A TOPICAL

SYNOPSIS OF LECTURES

ON

ANIMAL PHYSIOLOGY.

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PART I.

ANN ARBOR, MICHIGAN:
SHEEHAN & COMPANY.
1882.

ANN ARBOR REGISTER PRINTING AND PUBLISHING COMPANY.

AUTHOR'S NOTE.

This imperfect skeleton of a course of lectures on physiology has been prepared at intervals with the sole object of helping students to fix the attention upon the main facts of the subject. The topics have served simply as points of departure in the lecture room, and no effort has been made to render the "Synopsis" clear to any for whom the spaces between the paragraphs have not already been filled in. The author has been burdened by no desire for originality, and for good reasons the admirable text-books of Professor Martin and of Dr. Foster, especially the latter, have frequently been followed in both order and substance in the preparation of these notes.

ERRATA.

The following are some of the more important errors of the print:

Page	7, 15th	line	from	bottom,	for	fibrogen read fibrinogen.
"	9, 16th	"	"	top,	"	plamine read plasmine.
"	18, 17th	"	"	"	"	lanceloate read lanceolate.
"	21, 20th	"	"	"	"	contractlity read contractility.
"	27, 20th	"	"	"	"	envolved read evolved.
"	28, 9th	"	"	bottom,	"	is read it.
"	28, 4th	"	"	"	"	of read if.
"	35, 4th	"	"	"	"	is read is to.
"	39, 5th	"	"	"	"	pneumogatric read pneumogastric.
"	72, 18th	"	"	top,	"	direct of read direct.
"	82, 10th	"	"	bottom,	"	elimation read elimination.
"	102, 15th	"	"	top,	"	*astigmation* read *astigmatism*.
"	104, 9th	"	"	bottom,	"	complemetary read complementary.
"	106, 19th	"	"	top,	"	instrinsic read intrinsic.

I. THE OBJECT OF PHYSIOLOGY AND THE FUNCTIONS OF LIVING MATTER.

Physiology is the study of the chemistry and physics of the living body.

Physiologically Life is the sum of the functions of matter called Protoplasm.

Protoplasm is made up of the elements C, H, O, N; traces of P and S; some inorganic salts. Contains much water and probably residues of proteids, fats and carbohydrates.

To make protoplasm needs building material and building energy.

In the animal both are supplied by the food and oxygen taken in.

In the green plant sunlight supplies building energy.

Living protoplasm is continually wasting.

In the animal the waste matter contains less potential energy than the food; the energy difference is the vital force of the animal.

The general functions of all protoplasm are exhibited by the simplest living thing, as an *amœba*, or *white blood corpuscle.*

These functions are:

Contractility.
Spontaneity.
Irritability.
Conductivity.
Coördination.
Assimilation. This leads to *Growth* by *Intussusception.* Growth stops when the weight of *egesta* equals that of *ingesta.* As the amount of waste matter depends upon the *mass* of protoplasm and the amount of matter assimilated upon its *surface*, growth must have its limit according to the law of unequal increase of mass and surface.

Reproduction.

The highest animal exists first as an egg, a single cell.

Multiplication of cells by *fission.*

The body is composed of cells, modified cells and intercellular matter.

Differentiation of tissues.

Physiological classification of tissues into:—

Undifferentiated.

Supporting.

Nutritive; including *assimilative; secretory; receptive; eliminative; respiratory; metabolic.*

Storage.

Irritable.

Conductive.

Coördinating and *Automatic.*

Motor.

Protective.

Reproductive.

II. THE NATURE OF THE LAWS SUPPOSED TO RULE THE ACTIVITIES OF THE BODY.

The physiologist studies vitality as a manifestation of chemical and physical energy and believes the laws governing living and not living things to be equally inflexible.

Energy exists in two states, *Potential* and *Actual* or *Kinetic.*

Potential energy; represented in the position of masses; by position of atoms in molecules.

Kinetic energy; represented in the motion of masses and of molecules and atoms.

The different kinds of energy.

One kind of energy may be changed into another.

Energy is indistructible.

Energy cannot be created.

The uses of a machine as illustrated by the steam engine, the pulley and the watch spring.

The principle of the dissipation of energy.

Consider the whole history of the energy represented in a stone thrown by the arm into the air.

III. THE LYMPH AND BLOOD.

The fluid parts consists of food matters dissolved and altered by digestion and the activity of metabolic tissues, and of the products of tissue change.

LYMPH.

The tissue elements are bathed in lymph,

Physical and chemical characters of lymph. Lymph corpuscles.

Lymph derived from blood by diffusion.

Nature of diffusion; influence of temperature; of the dividing membrane; of the concentration and composition of the diffusing fluids.

Effect of blood pressure on the diffusion from the blood vessels. The use of the lymphathic vessels.

Various directions of the lymph currents of diffusion in the body.

Influence of the blood circulatlon on the rate of diffusion by the supply of new and removal of waste matter.

Physical and vital characters of lymph corpuscles.

Coagulation of lymph.

BLOOD.

Consists physically of straw colored fluid plasma and of solid red and white corpuscles.

Relative number of red and white corpuscles. Conditions of its physiological variation.

Size, shape, physical and vital characters of white corpusles.

Number, size, shape, physical characters and function of human red corpuscles.

Distinction between the red corpuscles of mammals and of other vertebrates.

Rouleaux of red corpuscles in drawn blood.

Stroma and hæmoglobin of red corpuscles.

Cause of opacity of blood. "Laky" blood and means of producing it.

Composition of hæmoglobin; hæmoglobin crystals.

Characters and production of hæmin crystals.

COAGULATION OF BLOOD.

Physical changes in blood on coagulating; jelly stage; solid clot; cupping; serum; "resolution" of clot.

Demonstration of fibrin threads in the clot produced on a microscope slide.

Phenomena of clotting in a capillary tube.

Effect of whipping fresh blood.

Physical components of blood	Before clotting	Plasma. Corpuscles.
	After clotting	Clot=fibrin+ corpuscles. Serum.

Whipped blood=corpuscles+serum.

Red corpuscles have nothing to do with coagulation.

The *buffy coat;* its nature and conditions of occurrence.

The reason for its occurrence in blood in inflammatory disease.

Relation of the shape of the clot to that of the containing vessel.

Color of clot at different distances from the free surface.

Uses of clotting to a wounded animal.

CAUSES OF COAGULATION AND INFUENCES MODIFYING IT.

Old theories that clotting was due to escape of ammonia; to taking up of oxygen.

Significance of blood clotting under mercury.

Hypothesis that the internal coats of the blood vessels prevent coagulation.

Evidence as to influence of internal coat.

View that blood does not tend to clot until chemically altered.

Influence on coagulation, of temperature; of strong solutions of mineral salts; of stirring.

White blood corpuscles always found in spontaneously coagulating fluids.

The deposit of fibrin around a foreign object in flowing blood is preceded by accumulation of white corpuscles.

In the thin clot upon a microscope slide the fibrin threads start from white corpuscles.

In slowly clotting horse's blood the firmest clot is at the level of greatest accumulation of white corpuscles.

Direct observation under the microscope of thrombus formation in a frog's tongue.

The disintegration of white corpuscles and transition forms on drawing blood from the body.

Denis' plasmine.

Clotting of the solution of plasmine.

Plasmine is a mixture of two fibrin factors, fibrinoplastin and fibrinogen.

Fibrinoplastin is in solution in blood serum; is precipitated by saturating with salines; is dissolved by dilute salines.

Fibrogen is found in solution in transudation fluids; is precipitated by saturating with salines; is dissolved by dilute salines.

Artificial clot from mixture of serum with transudation fluid; or from mixture of saline precipitates of the fibrin factors.

Physical characters of the two fibrin factors.

Necessity of salines to coagulation.

The action of the fibrin ferment.

The nature of animal ferments; conditions of action.

The origin of fibrin ferment and method of obtaining it.

The weight of the clot is less than that of the fibrin factors employed.

Fibrinoplastin is left over after clotting.

Part played by white corpuscles in the production of fibrin factors and of fibrin ferment.

THE TRANSFUSION OF BLOOD.

Transfusion as practiced on the isolated hearts of the frog and dog.

The nature of the foreign blood is not indifferent.

Danger in direct transfusion of clotting in the transmission tube.

Danger of injection of whipped blood because of its contained fibrinoplastin and fibrin ferment.

Experiments illustrating this point.

CHEMISTRY OF BLOOD.

Specific gravity of blood; relative weight of corpuscles and plasma.

Comparison of mass of corpuscles and plasma.

Reaction of blood; its variation in clotting.

The amount and kinds of gas given off in vacuum by a volume of blood; by serum.

Chemical composition of serum; nature of its solid matters.

The ash of serum contrasted with the ash of corpuscles.

Chemical composition of the red corpuscles; of the white.

HISTORY OF BLOOD CORPUSCLES.

Evidence for the transitory nature of the corpuscles; variation in number at different times; probable derivation of urinary and bile pigments; normal number quickly regained after hemorrhage.

Origin of the red corpuscles in the embryo; metamorphosis of mesoblastic cells; transformation of white corpuscles arising in the liver and spleen; from the protoplasm of connective tissue corpuscles.

Origin of red corpuscles in the adult; metamorphosed from transitional forms of white corpuscles found in the spleen and red medulla of bones.

Fate of red corpuscles; probably destroyed in the spleen.

White corpuscles; physiological variation in number. Arise in lymphatic glands and similar organs. They probably serve as occasional tissue builders, and give rise to red corpuscles.

THE QUANTITY AND DISTRIBUTION OF BLOOD IN BODY.

About one-thirteenth of body weight is blood: of this is contained

One-fourth in heart, lungs, large arteries and veins.
One-fourth in the liver.
One-fourth in skeletal muscles.
One-fourth in the remaining organs.

DEMONSTATIONS.

Whipped beef's blood.

Laky blood.

Method of obtaining hæmin crystals.

Separation of corpuscles and plasma in horse's blood prevented from clotting.

The clotting of plasma from horse's blood.

Plamine of Denis.

Precipitated fibrinoplastin.

Clotted horse's blood showing buffy coat.

Clot and serum.

The phenomena presented in the clotting of freshly drawn blood.

Effect of whipping freshly drawn blood; character of the fibrin obtained.

The clotting of blood under mercury.

IV. THE CHEMISTRY OF ANIMAL TISSUES.

All the activities of the body are due in the end to chemical processes.

The body is composed of living matter, protoplasm, and of not living matter which is made by protoplasm; otherwise, the body is composed of Formative and of Formed matter. In general, formative matter exists in cells while formed matter is intercellular.

The molecule of protoplasm contains residues of proteids, fats, and carbohydrates, besides salines and extractives.

PROTEIDS.

These form the principal solids of active tissues, of blood and of lymph.

The molecule is very complex; composed of many atoms of O, H, N, C, and S.

Proteids are amorphous.

All are non-diffusible except Peptones.

Mostly coagulated by alcohol and ether.

Soluble with change in strong acids and alkalis.

Chemical reactions; xanthoproteic; Millon's; caustic soda and copper sulphate, etc.

CLASSES OF PROTEIDS.

1. Native albumins; serum and egg albumin. Soluble in water.

2. Derived albumins or albuminates; acid and alkali albumin; casein. Not soluble in water but in dilute acids and alkalis. Not precipitated by boiling. All proteids dissolved in acid or alkali become albuminates.

3 Globulins; globulin; fibrinoplastin; fibrinogen; myosin. Not soluble in water but in dilute salines; precipitated by strong salines.

4. Fibrin. Insoluble in water and dilute salines. Soluble with difficulty in strong salines and dilute acids and alkalis.

5. Coagulated proteids, soluble only in strong acids and alkalis.

6. Peptones. Soluble in water. Not precipitated by acids, alkalis or boiling. Diffusible. Product of all proteid digestion. Many varieties.

NITROGENOUS NON-CRYSTALLINE BODIES DERIVED FROM AND ALLIED TO PROTEIDS, BUT NOT CAPABLE OF REPLACING PROTEIDS IN THE FOOD.

They contain the elements C, H, N, O, and sometimes S.

Mucin; a secretion of mucous epithelium.

Chondrin; the organic basis of cartilage. Its solutions set on cooling.

Gelatin; organic basis of bone, teeth and tendon. Solutions set on cooling.

Elastin; from elastic tissue. Its solutions do not gelatinize.

Keratin; from hair; nails; epidermis.

Nuclein; from nuclei of pus corpuscles.

COMPLEX NITROGENOUS FATS CHIEFLY FORMING PARTS OF NERVE TISSUES.

Lecithin.
Protogon.
Cerebrin.

STORE MATERIALS LAID UP IN THE BODY AS FOOD FOR THE TISSUES; FATS AND CARBOHYDRATES.

FATS.

Neutral fats are compounds of a fatty acid with glycerine.

They are made up of the elements C, H, O.

Insoluble in water. Soluble in ether, chloroform and hot alcohol.

Are decomposed by caustic alkalis forming soaps with them, leaving the glycerine free.

Palmitin.

Stearin.

Olein.

The fats occur mixed together in the body. Their fusion points differ. Their molecule contains much more C and H in proportion to O than does that of carbohydrates.

CARBOHYDRATES.—*Composed of C, H, and O.*

Dextrose or grape sugar; capable of alcoholic fermentation; of lactic acid fermentation.

Lactose or milk sugar; capable of lactic acid fermentaiion.

Inosit; capable of lactic acid fermentation.

Glycogen; convertible into dextrose.

Dextrin; convertible into dextrose.

SOME OF THE SUBSTANCES FORMED IN THE BODY; FOR THE MOST PART "WASTE" PRODUCTS OF TISSUE CHANGE.

NON-NITROGENOUS METABOLITES.

Lactic acid.
Oxalic acid, in oxalate of lime.
Succinic acid.

NITROGENOUS METABOLITES.

Urea; and its oxalate and nitrate.
Uric acid; and salts.
Kreatin.
Kreatinin.
Sarkin.
Leucin.
Tyrosin.
Hippuric acid.
Taurocholic acid.
Glycocholic acid.

DEMONSTRATIONS.

The reactions of proteids and characteristics of their groups.
The indiffusibility of albumin and dialysis of common salt.

V. EPITHELIUM, CONNECTIVE TISSUE, BONE, AND PHYSIOLOGY OF THE SKELETON.

EPITHELIUM.

The typical animal cell; cell membrane; protoplasm; granules; nucleus and nucleoli; fibrillar net-work.

Scaly or squamous epithelium; epidermis and buccal mucous membrane.

Columnar epithelium; intestine.

Pavement epithelium; mesentery.

Polyhedral epithelium; glands.

Ciliated epithelium; trachea.

THE CONNECTIVE TISSUES.

Function and distribution in the body.

White fibrous tissue; physical characters; swelled by acids; distribution.

Yellow elastic tissue; physical characters; unaffected by acids; distribution.

Cement substance.

Connective tissue corpuscles; varieties of form and function; distribution.

Gelatinous tissue; vitreous humor; umbilical cord.

Areolar tissue; composition and distribution.

The development and condition of fat in the body.

THE PERMANENT SKELETON.—CARTILAGE.

Hyaline cartilage; its physical characters; the perichondrium; contains no blood vessels; histological appearance; cells and matrix; method of formation of matrix; transition forms between round cartilage cells and branched periosteal cells; distribution and function.

Fibro-cartilage; physical and histological characters; action of acids; distribution and function.

Elastic-cartilage. Parenchymatous cartilage; physical and histological characters; unaffected by acids; distribution and functions.

THE BONY SKELETON.

The skeleton should be made of parts which are strong light, inflexible and symmetrical.

Bones are composed of a mixture of organic and earthy matter.

The former is flexible, the latter stiff and brittle; the original size and shape of the bone are retained when either is removed.

Two thirds of the weight of dry bone is mineral, chiefly $Ca_3\,2\,(P\,O_4)$.

Mechanical advantage of this combination.

THE LONG BONES.

The periosteum.

The expanded articular end of long bones allows distribution of strain.

The advantage gained by the hollow cylindrical form of the bone.

The cancellated extremities and the red and white marrow.

Histological structure of a long bone; the perfection of adaptation for firmness, lightness and elasticity.

THE SKULL.

Advantage of its curved shape.

The two bony tables with diplöe between.

The outer bony plate is thicker, tough and fibrous.

The inner bony plate is thinner, dense and brittle.

Use of diplöe in deadening jars.

Use of the sutures in limiting the extension of jars.

THE BACKBONE.

The separate vertebræ allow the bending of the spine.

The intervertebral pads allow bending without separation of vertebræ, and deaden jars.

The curved shape of the spine gives it a wide range of elasticity.

JOINTS.

Ball and socket joints.

Hinge joints.

Pivot joints.

Gliding joints.

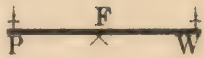
The synovial sac and its influence.

The capsular ligament.

Bones are held together by atmospheric pressure.

THE BONY LEVERS.

Lever of the first order; nodding motion of the head. . . . . . .



Lever of the second order; raising the body on the toes by the calf muscles. . . .

Lever of the third order; raising of forearm by the biceps muscle. . . . .

DEMONSTRATIONS.

Tendon.
Ligamentum nuchæ.
Mesentery.
Costal cartilage.
Articular cartilage.
Intervertebral cartilage.
Elastic cartilage.
Decalcified bone.
Sections of long bone and skull.
The skeleton.

VI. THE CONTRACTILE TISSUES.

AMŒBOID CELLS. CILIATED CELLS. MUSCLES.

Contractility is a function of Protoplasm irrespective of any special form in which this matter may be found.

All visible movements of higher animals are due to the contraction of a special set of organs, the muscles, which are in no case able to set up movements spontaneously.

The amœboid cells contract throughout their body substance and have usually the power of locomotion.

CILIATED CELLS.

Ciliated cells are fixed and are usually columnar in shape

The free margin of the cell is thick and firm, and has projecting from it from ten to thirty long protoplasmic lashes, the *cilia.*

The movement of the cilia is a to and fro whipping motion.

The movement is two or three times quicker in one direction than in the other.

Foreign bodies resting resting upon the cilia are urged in the direction of the more rapid motion.

The function of cilia in the trachea and bronchi: they cause expulsion of solid particles and aid the mixture of gases.

The movement is automatic and coördinated. The move, ment of a series of cilia is not isochronous, but proceeds in a wave form along the row.

The impulse to the movement is probably conveyed directly. from the protoplasm of one cell to that of the next.

The energy produced by each cell is calculated as sufficient to raise its own weight each minute 4½ metres.

THE MUSCLES.

The muscles are not automatically contractile.

They are usually red in color from contained hæmoglobin, but the color is not essential.

There are two great groups which are distinguished histologically and physiologically: (1) Plain or unstriated muscle; sometimes called visceral or organic or involuntary muscle. (2) Cross striated muscle; sometimes called skeletal or voluntary muscle.

All striated muscles contract quickly after a short latent period.

All non-striated muscles contract slowly after a long latent period.

The visceral or involuntary muscles of some animals are striated.

HISTOLOGY OF NON-STRIATED MUSCLE.

The flattened lanceloate cell; the rod shaped nucleus.

The method of aggregation of the muscle cells, and their distribution in the body.

THE STRIATED MUSCLES.

The manner of aggregation of muscle and other tissues as shown in the cross section of a limb. Each muscle is made up of separate bundles of fibres.

The fibres may be oblique or parallel to the long axis of the muscle.

The length of the muscle fibre in man varies from two feet to one quarter of an inch.

HISTOLOGY OF STRIATED MUSCLE.

The muscle fibre; the sarcolemma; the nuclei; the cross markings.

The cross marking is due to alternate bright, dark and dim bands.

The juncture of muscle fibres by their beveled endings.

Two modes of ending in tendon.

The greater part of the living muscle fibre is semi-fluid in consistency.

PHYSIOLOGY OF STRIATED MUSCLE.

The function of the muscle fibre is to contract or to draw its two ends nearer together.

Muscle exists in the body in two natural conditions, in an active and a passive state; the shape and elastic properties of the muscle are different in the two conditions.

The shortening of the muscle is active and due to distinct chemical processes; the elongation is passive.

The shortening is caused by the tranverse swelling of the fibres.

The muscle does not preceptibly alter in volume in contraction.

The molecular cause of contraction is probably the absorption of the more fluid parts of the muscle fibres within definite layers of more solid particles.

Whatever excites a muscle to contract is called a stimulus.

The contraction begins at the point stimulated, and moves along the fibre in the form of a wave, which travels in the frog's muscle with a velocity of about three metres per second. The wave moves slower the lower the temperature.

THE PHYSICAL PROPERTIES OF MUSCLE.

Compare the curve of elasticity of muscle with that of steel.

Compare the curves of elasticity of resting and active muscle.

The elasticity of resting muscle is perfect within narrow limits.

When a muscle contracts, its elasticity decreases and its extensibility increases.

The resting muscles in the body are always slightly stretched between their attachments. Proof of this and significance for the welfare of the body.

The protective use to the body of the increased extensibility of contracted muscle.

The elasticity of the muscle enables it to store up its energy of contraction.

The lifting power of the muscle diminishes with contraction.

Show how in the movements of the bony levers the contractile energy of the muscle is economized according to the preceeding principle.

The muscle posesses the distinct properties of *contractility, conductivity* and *irritability.*

Irritability is the capability possessed by some tissues of being stirred up to functional activity by a stimulus.

Its peculiarity is the disproportion between the amount of energy represented in the stimulus and in the effect produced.

Irritability is decreased by low temperatures, by fatigue, by various drugs.

The old view that contraction of muscle was due to swelling of its subtance by the inflow of "animal spirits."

Proofs of the independent irritability of muscle; contraction of embryonic muscles before the establishment of nervous connections; the "idio-muscular" contraction; the nerve free ends of the sartorius; the manner of action of *curare.*

The various kinds of stimuli capable of exciting muscle; nervous; mechanical; thermal; chemical; electrical.

The character of a muscular contraction caused by the application of a galvanic current.

The contraction caused by a single inductive shock.

The general law for the stimulation of irritable tissues: It is only the *change of intensity* of a stimulus that excites an irritable organ.

The most favorable rate of change of intensity of the stimulus differs for different kinds of tissues; the intensity should vary most rapidly for nerve, less so for striped muscle and still more slowly for unstriped muscle.

The muscle answers a single stimulation by a single twitch or contraction.

The contraction is prolonged by cold, by fatigue, by varions drugs.

The curve of a single muscular contraction; the latent period of stimulation; the phases of the contraction curve; the "contractur."

The latent period of stimulation is the interval elapsing between the application of a stimulus and the beginning of contraction. Its average duration in the frog's muscle is .01 second. During the latent period the muscle molecules are undergoing chemical, electrical, thermal and mechanical changes. The period is lengthened by cold, by fatigue, by increased load.

The "contractur" is due to the "elastic after action" of the muscle substance, not to vital changes. Influence of fatigue and of load upon the contractur.

Maximal and sub-maximal single contractions; with a certain strength of stimulus the muscle gives a barely visible contraction; with increase of stimulus the height of contraction increases to a certain extent, and then no stronger stimulus causes a greater contraction.

The fatigue curve of muscle excited to single contractions repeated at a definite rate is a straight line. The line falls more rapidly with a shorter interval between the stimuli. The effect of rest is to increase the height of the succeeding contraction.

The waste products of contraction diminish the irritability and contractlity of the muscle. A blood free muscle exhausted by stimulation may be made to contract again after washing out with dilute salt solution.

The work done by a contracting muscle is measured by the load × height of lift. The work done increases with the load to a certain extent and then diminishes as the load becomes greater.

The lift power of a muscle increases with its thickness, or the number of fibres side by side. The extent of the shortening increases with the length of the fibres.

PHYSIOLOGICAL TETANUS.

When one contraction succeeds another in a muscle before the first is finished, the result is a longer and more extensive contraction or *tetanus*. The tetanus is smooth when each contraction begins during the ascending phase of the preceeding one. The tetanus is vibratory when the muscle has time to relax from one contraction before another engages it.

Proof of the formation of tetanus by the summation of single contractions.

A tetanus may be sub-maximal or maximal in extent.

A muscle may be shortened by tetanus to one-third its original length.

In tetanus the *duration*, the *amplitude*, and the *power* of the contraction may be made greater than by the use of a single stimulus.

The natural contractions of the living body are sub-maximal and tetanic in character.

Proofs of the foregoing statement: comparsion of the power of voluntary and artificially excited contractions. The duration of the shortest voluntary contraction compared with that excited by a single artificial stimulation. The muscle note and its pitch.

Voluntary contractions are probably due not to the simultaneous, but to the successive stimulation of the different fibres of a muscle.

Free circulation of blood in the muscle is necessary to voluntary contraction.

THE ELECTRICAL PHENOMENA OF ACTIVE MUSCLE.

When a muscle is stimulated, the part excited becomes electro-negative to the resting parts.

The electric change is due to the chemical changes of the active molecules.

The chemical change set up in the muscle by stimulation is conducted along the fibres, and the electro-negative condition accompanies it.

The rate of this progression in the frog's muscle is about three metres per second. It has already finished its course during the latent period of stimulation.

If an electric conductor be made to connect the excited electro-negative part of the muscle with its resting electro-positive part, a current of electricity will flow through the conductor. This current is called the "action current" of the muscle.

Experiment of the "rheoscopic frog." The secondary mus-

cle is thrown into tetanus when the primary muscle is tetanised, thus proving the interrupted nature of the electric changes in the latter.

When the vital continuity of the nerve supplying the first muscle is broken by tying a string around it, the tetanus fails in both muscles.

An action current is set up in a muscle by any stimulus, electrical or otherwise.

The secondary contraction of a frog's nerve-muscle preparation caused by the beat of the mammalian heart.

COMPARISON OF THE PHYSICAL AND CHEMICAL CHARACTERS OF LIVING AND DEAD MUSCLE.

Living resting muscle is soft, glistening, elastic, semi-transparent and alkaline or amphichroic in reaction.

Living working muscle is less elastic, but more extensible and becomes acid in reaction.

Dead muscle is dull, opaque, inelastic and is acid in reaction.

A dying muscle loses gradually its irritability, and then goes rather suddenly into *rigor mortis.* Rigor is attended by a considerable production of sarcolactic and carbonic acids, by a rise of temperature and by a shortening of the muscle. Rigor passes off as decomposition sets in.

THE CHEMICAL CHANGES OF WORKING MUSCLE.

The excised muscle gives off no oxygen under the air pump, but when made to contract it develops sarcolactic and carbonic acids in an oxygen free atmosphere.

The living muscle in the body consumes more oxygen, and produces more carbonic acid in the active than in the resting condition.

The weight of muscle substance soluble in water decreases, while that soluble in alcohol increases in the active as compared with the resting condition.

The amount of acid produced by tetanising an excised muscle is substracted from the amount finally produced by the death of the muscle.

The living muscle molecule probably consists of an essential nitrogenous part capable of building on to itself certain carbon compounds by whose oxidation the energy of contraction is produced.

Every contraction is attended by an evolution of heat.

Comparison of the muscle with the steam engine.

THE CHEMISTRY OF LIVING MUSCLE.

The contents of the living muscle fibre are chiefly semi-fluid in consistency. This matter is the *muscle plasma.*

The artificial preparation of muscle plasma.

The clotting of muscle plasma and its separation into clot and serum.

The muscle clot is *myosin*; its formation in dead muscle causes *rigor mortis.*

The clot of myosin is granular; its formation is accompanied by the development of acid.

THE CHEMISTRY OF DEAD MUSCLE.

The dead muscle contains seventy-five per cent. water. Its dry substance contains:—

Proteids; myosin; serum albumin.

Extractives; kreatin; sarcolactic acid; xanthin; hypoxanthin; uric acid; inosit (in the heart); inosinic acid; sugar.

No urea.

Fats in quantity.

In living muscle there is glycogen which is changed to sugar on death. The nitrogenous extractives are products of the chemical changes of the muscle substance. Myosin does not exist in living muscle.

THE PHYSIOLOGY OF UNSTRIATED MUSCLE.

Unstriated muscle is not found unmixed with other tissues of the body.

Organs containing unstriated muscle have to some extent power of automatic contraction, which may be due to contained nervous elements.

The contraction progresses slowly in a wave form from the spot stimulated, and is preceeded by a long latent period.

In striated muscle the contraction waves passes only lengthwise throughout the fibre; in unstriated muscle the wave may pass both in the direction of the length and the breadth of the cell.

The impulse to contraction may probably be communicated directly by one muscle cell to another without the intervention of nerves.

Unstriated muscle is more readily stimulated by the make and break of a galvanic current than by induction currents.

Consider the action of unstriated muscle as seen in the peristaltic action of the intestine and ureter and in the contraction of the urinary bladder.

DEMONSTRATIONS.

The motor power of cilia.

Comparison of the contractions of striated and unstriated muscle in the rabbit.

The contraction of muscle on mercury.

The diminution of lifting power with the shortening.

The single muscular contraction and its curve.

Physiological tetanus and its curve.

The analysis of tetanus.

Maximal and sub-maximal contractions.

Contraction with the constant current.

The action of curare.

The rheoscopic frog; secondary tetanus.

Secondary contraction of frog's muscle from the beat of the mammalian heart.

Formation of acid with the death of the muscle.

VII. NERVOUS TISSUES.

The nervous tissues consist of the nerves and of the peripheral and central irritable non-contractile organs in which they end.

THE MINUTE STRUCTURE OF NERVES.

Nerve fibres are bound together in bundles, the *funiculi.*

Each funiculus is inclosed in several sheets of membrane, the *neurilemma.* Each nerve is composed of many funiculi inclosd in a common sheath.

The lymph channels of nerves.

Nerve fibres fall into two groups: (1) Medullated or white nerve fibres. (2) Non-medullated, gray or sympathetic nerve fibres.

Histology of the medullated fibre; the primitive sheath; the medullary sheath or white substance; the axis cylinder; the neuro-keratin frame work; the nodes of Ranvier; the cement substance; the nuclei.

Significance of the nodes to the nutrition of the nerve.

The medullary sheath is chiefly fat, and is invisible in perfectly fresh nerve.

The axis cylinder is protoplasmic and is the conductor of the nervous impulse.

Nerves lose their medullary sheath before reaching their peripheral and central terminations.

The ending of nerves in voluntary muscles; ending in involuntary muscle.

Histology of gray nerve fibre; absence of medullary sheath; nuclei found in the substance of the fibre.

The physiology of gray nerve fibre.

In general, the gray nerve fibres arise from the sympathetic system and are distributed to organs whose function does no involve consciousness.

CLASSIFICATION OF NERVES ACCORDING TO THEIR FUNCTIONS.

- Peripheral Nerves.
  - Afferent
    - Sensory.
    - Reflex.
    - Excito-motor.
    - Vaso-motor.
    - Inhibitory ?
  - Efferent
    - Motor.
    - Vasomotor.
    - Secretory.
    - Trophic?
    - Inhibitory.
- Intercentral Nerves.
  - Exciting.
  - Inhibitory.
  - Commisural.

PHYSIOLOGY OF NERVES.

The nerve is not automatic, but possesses to a high degree *irritability* and *conductivity.*

The nerve is excited only by the change of intensity of a stimulus.

The nerve is excited by a much weaker induction shock than is the muscle.

Various nerve stimuli; mechanical; thermal; chemical; electrical.

The chemical change started by an artificial stimulation travels as a nervous impulse along the nerve in both directions.

As in the muscle, the excited parts of the nerve are electronegative to the resting parts. The *action current* and the chemical change causing it travel along the nerve of the frog at the rate of about twenty-eight metres per second, and of man thirty-three metres per second.

The irritability of the nerve and its rate of conduction increase with the temperature.

The energy of the nervous impulse is small in amount. No heat can be shown to be envolved and no chemical change to take place as a result of nervous activity.

All the phenomena of muscular contraction obtained by the direct stimulation of the muscle substance may be obtaind by its indirect stimulation through the nerve.

The degeneration and regeneration of cut nerves.

ELECTROTONUS.

When a motor nerve is subjected to the passage of a constant current of electricity the muscle supplied by it contracts only at the make and break of the current in the nerve, and remains at rest during the passage of the current.

The passage of a galvanic current modifies the irritability and conductivity of the nerve.

The irritability and conductivity of the nerve are *diminished* in the neighborhood of the *anode*, and *increased* in that of the *kathode* of the constant current.

Inthe region of diminished irritability the nerve is said to

be in the state of *anelectrotonus*. In the area of exalted irritability the nerve is said to be in *kathelectrotonus*.

The electrotonic conditions are more marked the stronger the galvanic current used.

Proofs of the electrotonic modifications of irritability as exhibited on the excised nerve-muscle of the frog and on the human arm.

DEMONSTRATIONS.

The indirect stimulation of muscle through the nerve.

Maximal, sub-maximal contractions and tetanus indirectly obtained.

Proof of the greater irritability of nerve-muscle than of curarised muscle toward induction shocks.

Various nerve stimuli; chemical; mechanical; thermal.

Contraction with the use of the galvanic current.

The electrotonic modification of irritability of nerve.

VIII. REFLEX ACTION AND THE MECHANISMS INVOLVED IN IT.

The origin of nerves from nerve cells.

Various forms of ganglion cells. Nerve cells in sporadic ganglia; in the spinal cord; in the cerebellum; in the cerebrum.

In the living body every contraction of the skeletal muscles is due to stimuli proceeding from nerve cells.

NATURE OF THE CONTRACTIONS PRODUCED BY THE DIRECT STIMULATION OF THE NERVE CELLS.

Make one cut across a motor nerve and the muscle supplied by is contracts but once.

Cut across the spinal cord of a frog and its muscles are thrown into *tetanus*.

The tetanus involves only the flexor muscles if the section be made across the anterior part of the cord. Only the extensor muscles are contracted of the section severs the posterior part of the cord.

The experiment indicates that a nerve cell when artificially excited may continue to send out discharges after cessation of

the stimulation. Also that there is localization of motor function in the spinal cord.

REFLEX ACTION.

Nerve cells communicates with the exterior by means of afferent nerve fibres.

External phenomena excite afferent nerves through the medium of *sense organs* in which those nerves terminate peripherally.

The nervous organs in which nerves terminate are excited only by a change in the intensity of a stimulous.

Examples of sense organs; the retina; the organ of Corti; tactile corpuscles.

The reflex action obtained by dipping the toe of a headless frog into dilute acid.

Characters of the reflex. The latent period or *reflex time* The apparently purposeful character of the reflex in removing irritating substances.

Purposeful character of a reflex as shown in sneezing and coughing.

A single stimulus with difficulty provokes a reflex, but a succession of stimuli readily does so. Summation of stimuli in the spinal cord.

Increase of strength of stimulation or increase of its rate shortens reflex time.

The reflex time is the period occupied chiefly by processes in the nerve cells.

The uncoördinate nature of reflexes obtained by direct stimulation of the afferent nerve.

The value of the peripheral nervous organ in reflex action. Each sense organ is differentiated to be specially irritable toward one certain form of energy.

Radiation of nervous impulses in the cord.

The purposful character of reflex actions explained not by consciousness of the cord but by the choice of *paths of least resistance* which determines the direction taken in the cord by impulses arising from any quarter.

Any segment of the spinal cord may act as a reflex centre.

The typical mechanisms employed in a normal reflex action are: A peripheral organ for the reception of the stimulus, an afferent nerve fibre, a single nerve cell or a sensory and a motor cell, an efferent nerve fibre, a peripheral motor or glandular organ.

The essential characters of a reflex action are: (1) Its unconsciousness; (2) the want of likeness between the effects produced and the nature and method of the stimulation employed; (3) the usually coördinated nature of the action.

The most rapid action of which the central nervous system is capable is manifested in reflexes.

Modification of the conductivity of the spinal cord in strychnia poisoning.

INHIBITION.

The activity of a nervous centre is the resultant of two forces, one exciting to discharge and the other resisting discharge. Forces resisting or depressing activity are termed *Inhibitory.*

The resistance to the action of any nerve cell seems to be increased by its association with the nerve cells in physiolgical connection with it.

Inhibitory influences may reach an active nerve cell from any quarter, as along any afferent nerve.

Consider the inhibition of a reflex action through the strong stimulation of an efferent nerve.

There appear to be in the brain special inhibitory centres whose business it is to send out impulses to retard or depress the activities of the body.

Consider the inhibitory effect upon reflex action in the frog of stimulation of the optic lobes. The inhibition of the beat of the heart.

Reflex time is the period occupied by a stimulus in overcoming the resistence to discharge offered by the nerve cell.

The physiological relation of reflex and voluntary actions. Cerebral time.

The tendon reflex.

Muscular tone.

There is no proof that the sporadic ganglia of the body can serve as reflex centres.

The physiological afferent and efferent nerve fibres are mixed together in the nerve trunks, but before reaching the spinal cord the sensory and motor fibres separate, the former joining the cord by the posterior spinal root, and the latter by the anterior root.

DEMONSTRATIONS.

Tetanus following section of the spinal cord in the frog.

Reflex actions from headless frog brought about by mechanical, electrical and chemical stimulation. Influence of the strength of the stimulus.

Reflex from stimulation of an afferent nerve.

The summation of electrical stimuli in the nervous centre.

The purposeful and coördinated character of the reflex shown in the removal of acid paper.

Inhibition of reflex by stimulation of an afferent nerve.

Influence upon reflex time of stimulation of the optic lobes in the frog.

Effect of strychnia upon the frog.

Demonstration upon the frog of the functions of the spinal nerve roots.

IX. THE CIRCULATION OF THE BLOOD, AND THE ORGANS OF CIRCULATION.

THE ANATOMY AND HISTOLOGY OF THE MAMMALIAN HEART.

The pericardium; its shape, dimensions and manner of attachment to the heart and chest wall.

The pericardial fluid.

The division of the heart cavity into four distinct chambers, those of the two auricles and the two ventricles.

The marked difference in thickness between the walls of the auricles and ventricles. The difference between the walls of the walls of the right and left ventricle.

An inner layer of muscle is peculiar to each auricle and an outer layer is common to both.

The spiral arrangement of the ventricular muscle fibres.

The comparative volume of the auricle when collapsed and when distended. The auricular appendage.

Compare the relative size of the four chambers of the empty heart.

Notice the size, shape and manner of attachment of the mitral and tricuspid valves. The muscle fibres upon the upper surface of the valves. The papillary muscles and the *chordæ tendineæ.*

The *columnæ carneæ.*

Notice the form and structure of the vessels springing from the heart.

Notice the shape, structure and manner of attachment of the semilunar valves.

Notice the shape of the aorta at its base, and the position of the openings of the two coronary arteries.

Observe the fibrous rings surrounding the auriculo-ventricular and arterial orifices.

Notice the muscle fibres continuing from the heart upon the surface of its great veins.

The endocardium.

The histological characters of the heart muscle. The muscle is made up of striated, nucleated cells not enclosed in sarcolemma.

The intrinsic ganglia of the heart.

The extra-cardiac nerves:—(1) fibres from the vagus nerve, including physiological efferent cardio-inhibitory and physiological afferent "depressor" fibres. (2) Fibres from the spinal cord by way of sympathetic ganglia, including physiological efferent "accelerator" fibres.

THE STRUCTURE OF THE BLOODVESSELS.

Tunica adventitia of the arteries.

The thick arterial wall and open lumen of the empty vessel.

The thin walled veins, collapsing when empty.

Minute structure of a small artery:—The lining epithelium. The thickness of the wall composed of three distinct coats; (1) a narrow internal coat composed chiefly of white fibrous connective tissue; (2) a thicker middle coat of circularly arranged unstriped muscle; (3) an outer less firm coat composed of mixed yellow elastic and white fibrous tissue.

In the larger arteries the constituents of the three coats intermingle, while in the arterioles the coats are sharply defined one from the other.

The muscular element becomes proportionally more prominent as we proceed from the larger to the smaller arteries.

The capillaries, composed intirely of the vascular endothelium cells joined edge to edge.

The structure of the veins corresponds in general with that of the arteries, except that the layer of muscle is not so well defined nor relatively so thick.

The valves in the veins.

Compare the elasticity of the artery with that of the vein. The artery is very elastic, its walls thick and strong. Curve

of elasticity of the arterial wall. The vein is more extensible than the artery and more easily ruptured when fully distended.

THE PHYSIOLOGY OF THE HEART.

THE AURICULO-VENTRICULAR VALVES.

Notice that the surface of the valves is considerably greater than is necessary to separate completely the cavity of the auricle from that of the ventricle on each side of the heart.

Notice that the *chordæ tendineæ* are attached externally not directly to the heart wall, but through the medium of the papillary muscles. The function of these muscles in keeping their tendons tense as the heart cavity becomes smaller in contraction.

The inner ends of *chordæ* springing from each papillary muscle are attached to the edges not of a single valve but to those of two adjacent ones.

The use of the muscle fibres upon the upper surface of each valve.

The floating upward of the auriculo-ventricular valves during the pause of the ventricle.

The function of the auricle in completely closing by its contraction the auriculo-ventricular valves.

The manner of action of the semilunar valves.

THE FUNCTION AND COMPARATIVE PHYSIOLOGY OF THE HEART.

The heart acts simply as a pump whose valves enable it to send fluid round a continuous circuit.

Diagrams illustrating the action of simple and complex pumps.

The object of the circulation is bring new material to the tissues and remove waste matters from them.

The mammalian heart is a double pump; one-half of which forces out venous blood and the other half arterial blood. The

use to the animal of this complex form of the mammalian heart.

Demonstration of the movement of fluid in the sheep's heart.

The coördination throughout the animal kingdom of the anatomical structure of the heart with the physiological needs of the organism:—The contractile circulatory apparatus of the *amœba;* of a *worm;* of a *snail;* of a *frog.*

THE PHENOMENA INVOLVED IN THE CARDIAC CYCLE.

The beat of the excised heart of the frog. The active *systole* and the passive *diastole.* The rounder base and shorter long axis of the heart in systole.

The position of the mammalian heart in the living body; the change of position on opening the chest wall.

The movements of the living heart within the chest:—The slight rotation round the long axis. The marked movement of base toward the apex, and its cause. Effect upon the position of the heart and on the movement of its base, of bleeding. The absence of locomotion in the apex.

The phases of the cardiac cycle:—The duration of the auricular systole and the condition of the rest of the heart during it. The duration of the ventricular systole and the condition of the rest of the heart during it. The duration of the common diastole of the heart. The length of the whole cardiac cycle.

The nature and time relations of the changes going on within the various chambers of the heart throughout the cardiac cycle. The experiments of Chauveau and Marey.

The cardiac systole begins in the great veins.

The quick peristaltic contraction of the auricles.

The simultaneous contraction of all the ventricular fibres.

The long persistence of the phase of extreme contraction in the ventricle.

The ventricles probably empty themselves completely at each systole. The auricles never do.

THE WORK DONE BY THE HEART.

Factors which determine the amount of work done by the heart:—(1) The amount of blood pumped out at each beat; (2) the resistance to be overcome; (3) the frequency of the beats.

The work power of the heart is alone quite sufficient to cause the blood to circulate through the whole body.

THE SECONDARY MECHANICAL AIDS TO THE WORK OF THE HEART.

The assistance given to the filling of the auricles by the movements of inspiration.

The suction of blood into the auricles due to the movement of the base of the ventricle when the latter contracts.

The help offered by the coronary circulation to the filling of the ventricle.

The help offered by the elasticity of the ventricular wall to the filling of the ventricle.

The circulatory variations in organs outside the heart as shown by the plethysmograph.

The aid rendered to the filling of the ventricle by the slipping of the ventricle over the auricle in ventricular diastole, due to the aortic pull.

THE INFLUENCES WHICH INITIATE AND MAY MODIFY THE BEAT OF THE HEART.

The cardiac beat is an automatic action and may be carried on in a normal manner by the excised organ.

The impulse to activity is discharged rhythmically, probably from certain nerve centres within the substance of the heart. But the rate and nature of the beat are profoundly modified by various secondary influences. The following are the secondary influences which may be shown to operate on the heart, and to their variation must be due any alteration in the character and rhythm of the automatic beat:—

1. The intra-cardiac blood pressure. The *diastolic* intra-cardiac pressure depends upon the volume of blood which flows into the heart. The *systolic* intra-cardiac pressure depends upon the resistence to the flow of blood from the heart, or upon thc blood pressure within the aorta and pulmonary artery.

2. The temperature of the blood entering the heart.

3. The chemical constitution of the blood supplying the heart.

4. The efferent nerves reaching the heart from extra-cardise centres.

THE INFLUENCE UPON THE HEART BEAT OF INTRA-CARDIAC BLOOD PRESSURE.

The heart of the frog cut out from the body and empty beats very feebly or comes to rest after a while; pass through its cavities a weak saline solution under pressure and the beats become much stronger or go on again for a time. *Distension of the cardiac wall is a stimulus to the activity of the heart.* The effect is more striking and lasting if blood instead of salt solution be used.

When the excised heart is normally beating with an artificial supply of blood, neither variation of arterial pressure nor variation of venous pressure produces any definite alteration in the rhythm of the heart beat. The *rhythm* of the heart beat is not directly affected by changes of intra-cardiac pressure.

The work done by the heart and the *force* of its beat increases with intra-cardiac blood pressure.

The normal heart is at any moment able to accomplish much more than it is normally required to do.

INFLUENCE OF THE TEMPERATURE OF THE BLOOD ENTERING THE HEART.

The heart muscle is extremely susceptible to changes of temperature. The rhythm of the beat is uniformly quicker with a higher and slower with a lower temperature. Changes

in the temperature of the blood amounting to a fration of a degree alter the rhythm of the mammalian heart beat.

INFLUENCE OF THE CHEMICAL CONSTITUTION OF THE BLOOD SUPPLYING THE HEART.

The heart is remarkably insensitive to deterioration in the nutritive fluid supplying it. The action of the frog's heart under minute quantities of nutritive material. The beat of the isolated mammalian heart supplied by blood poor in oxygen and rich in waste matters.

But the heart is very sensitive to the action of certain drugs. Certain of these affect the muscle of the heart directly, others operate on various parts of its intrinsic nervous mechanism.

The action of alkali on the heart muscle.

The action of acid on the heart muscle.

The action of digitalin on the heart muscle.

The action of atropin on the nervous mechanism.

The action of muscarin on the nervous mechanism.

THE INFLUENCE OF EFFERENT NERVES REACHING THE HEART FROM EXTRA-CARDIAC CENTRES.

Modifications of the heart beat are probably normally nearly altogether due to impulses proceeding along the heart nerves whose centres are no doubt much more sensitive to changes of external conditions than is the heart itself. The heart is merely the pump, the extra-cardiac centres the intelligence that modifies the action of the pump according to the needs of the body.

The *cardio-inhibitory* nerve:—fibres arising from the spinal accessory nerve join the pneumogatric trunk within the skull and are given off from this nerve again in the neighborhood of the heart. Stimulation of the peripheral end of the cut vagus causes slowing of the heart beat if the stimulation be weak, stops the beat if stimulation be strong.

The inhibition due to stimulation is preceded by a latent period of one or two heart beats.

Exhaustion of the inhibitory fibres: after being brought to a standstill, the heart soon commences to beat again though the stimulation be kept up.

Evidence for the constant action of the vagus inhibitory fibres upon the heart.

The vagus probably contains two other separate sets of fibres whose action in the one case strengthens, in the other causes weakening of the heart beat, without alteration of its rhythm. Evidence derived from the heart of the frog and terrapin.

The cardiac *accelerator* fibres arise from the spinal cord and reach the heart through the last cervical and first thoracic sympathetic ganglia.

Effect of stimulating the peripheral end of the spinal cord divided in the neck, or the peripheral ends of the divided accelerator fibres.

The heart beat is quickened by the stimulation. The stimulus required is much stronger than for the inhibitory nerve. The latent period is long, and the effect of the stimulation persists for some time after the cessation of the latter.

When the cardio-inhibitory and the accelerator fibres are simultaneously stimulated, the heart is brought to a standstill as if the vagus alone were irritated.

THE AUTOMATICITY OF THE HEART.

The phenomena offered by the frog's heart when it is cut in different directions and when its various parts are separated from each other.

The graded automaticity of the different parts of the heart; the decline of physiological resistance to discharge from the venous sinus to the ventricle.

The isolated ventricle of the frog's heart does not beat spontaneously, but rhythmic beats follow when it is distended with fluid.

The function of the ventricles is to drive the blood respectively in its pulmonary and systemic circulation.

The function of the auricles is, by the frequency and character of their pulsation, to regulate the rate and character of the ventricular contraction. And also by its beat to complete the closure of the auriculo-ventricular valves.

The law for the contraction of cardiac muscle:—Every stimulus that can call forth a beat at all produces a maximal beat. Stimuli of whatever strength are succeeded by contractions of the same force. Unlike the skeletal muscles, cardiac muscle refuses to give sub-maximal contractions on applying weaker stimuli.

The heart's contraction is probably not a tetanus but a long continued single contraction.

The action current of the heart.

THE APEX BEAT AND THE SOUNDS OF THE HEART.

The apex beat felt outside the chest wall lasts throughout the systole of the ventricle and is due to this. The impulse is due probably not to a blow of the heart's apex against the chest wall, but simply to the hardening of the heart muscle.

Thc two sounds of the heart; the time of their occurrence in the cardiac cycle and their difference of quality.

The first sound; probably both muscular and valvular in origin.

The second sound; due to the snapping to of the semilunar valves.

THE CIRCULATION OF THE BLOOD.

Proof that the work power of the heart is sufficient to complete the circulation of the blood.

Rate of the circulation; the blood completes its circuit from ventricle to ventricle in man in about 23 seconds.

The area of the arterial vascular bed increase from the heart to the capillaries and then decreases in the veins to the heart. The flow of blood is slowest where it passes

through the greatest area, that of the capillaries. The sum of the areas of cross section of the systemic capillaries is probably eight hundred times as great as that of the aorta.

The circulation of the blood as observed in a frog under the miscroscope. The comparison of the flow in arteries, capillaries and veins.

The "axial" current; the "inert" layer; the respective movements of white and red corpuscles.

The changes in the circulation brought about by the process of inflammation.

THE HYDRAULICS OF THE CIRCULATION.

The agents concerned in the circulation;—(1) An incompressible fluid; (2) A pump of intermittent action; (3) A set of elastic tubes.

If an artery be cut across there is a continuous flow of blood from its central end with an increased spurt at each heart-beat. Cut across a vein and there is steady flow of blood without pulsation from its peripheral end.

If a mercury manometer be attached to an artery of a living animal the position of the mercury will show that the blood in the artery is under considerable pressure, the *blood pressure*, which fluctuates with each beat of the heart.

If a manometer be attached to a vein the mercury will show a very small blood pressure and no pulsations.

Consider the causes:—(1) of the high arterial and low venous blood pressure; (2) of the continuous flow of blood brought about by the intermittent action of the pump; (3) of the loss of the pulse in the veins.

The law of the fall of fluid pressure in a tube offering equal resistance to flow in all its parts.

The *minor arterial schema.*

The *major arterial schema.*

The resistance to the movement of the blood is internal; that is, due to the friction of the fluid particles against each other. Conditions determining internal and external friction in the movements of fluids.

The internal friction increases fast as the calibre of the vessels decreases; hence the chief resistance to the circulation is in the capillaries, or is *peripheral.*

Because of the peripheral resistance the arterial walls are. stretched by the blood pumped from the heart, and the strained wall reacting on the fluid produces the high arterial pressure.

The arterial walls being kept constantly stretched, they squeeze constantly upon the inclosed fluid; hence the flow from a cut artery is continuous.

If the heart stop, the circulation continues to go on until the arteries have come to a condition in which they are not stretched.

The *blood pressure* is the *immediate* cause of the circulation. The action of the *heart* is its *remote* cause and operates through keeping the arteries stretched by forcing into them fresh quantities of fluid.

The energy of the blood pressure is used up in overcoming resistance to the circulation and as the chief resistance is offered by the capillaries, there is a sudden fall of pressure between the arteries and the veins.

Weber's Schema.

Each new quantity of fluid thrown into the base of the aorta distends the vessel there and this distension runs along the artery as the *pulse wave.*

The rate and height of the pulse wave depend upon the elastic qualities of the arterial wall.

The pulse wave started at any systole of the heart, travels much faster than the blood whose entrance into the aorta caused it.

The energy of the pulse wave is used up in stretching the vascular wall; hence the height of the wave decreases from the heart outwards.

Primary and secondary pulse waves.

Study of sphygmographic tracings.

The veins alone could contain all the blood of the body.

The arteries are *overfull.*

THE USE OF ARTERIAL ELASTICITY.

A greater amount of fluid is forced by a pump in a given time through an elastic tube than through a rigid one of the same calibre.

The energy of the heart's systole is stored in the arterial wall and acts throughout the cardiac cycle as driving force of the blood. By this means the useful energy of the heart is not limited in time to its systole, but is distributed through the whole cardiac cycle. Consider the analogy of many artificial machines. Consider the results to the heart and the circulation of the arteries being rigid tubes.

All the energy of motion that is lost to the blood in its circulation reappears as heat and goes to warming the tissues.

As the arterial blood pressure is the force which drives the blood round its circuit, it is of vital importance to the animal that a pretty constant mean pressure be maintained.

MEANS BY WHICH ARE REGULATED THE GENERAL BLOOD PRESSURE AND LOCAL BLOOD SUPPLY.

The factors which determine the power of the blood pressure are three:—(1) The force and frequency of the heart beat as determining the quantity of blood pumped into the arteries. Other things being equal, blood pressure increases with the quantity of blood forced out of the heart in a given time.

(2) The peripheral resistance; arterial pressure increases and venous pressure proportionately decreases as the peripheral resistance becomes greater, other factors remaining the same.

(3) The elasticity of the arteries; other things remaining equal, blood pressure increases with increase of elasticity, or resistance to distension, of the arterial walls.

Inhibition of the heart's action through stimulation of the vagus nerve causes a sudden fall of blood pressure.

Quickening of the heart's action by stimulation of the accelerator nerves does not alter the blood pressure.

THE VASO-MOTOR REGULATION OF BLOOD PRESSURE.

Withdrawal of a large quantity of blood from an animal does not lower, except momentarily, the blood pressure.

The injection of a large quantity of foreign blood into the vessels of an animal produces no permanent rise of blood pressure.

When the spinal cord of an animal is divided in the neck the mean arterial blood pressure decreases to a small fraction of it former value. When the peripheral end of the cut cord is stimulated arterial pressure rises again. Both the fall and the rise of pressure are somewhat gradual.

The vaso-motor centres in the *medulla oblongata.*

Efferent impulses proceed from the vaso-motor centre along vaso-motor nerves to all parts of the body and keep the muscular coats of the small arteries and arterioles in a state of tonic contraction, thus increasing the peripheral resistance to the flow of blood.

Secondary vaso-motor centres in parts of the brain other than the *medulla oblongata.*

It is not proven, but is not improbable that the capillaries are under vaso-motor control.

The experiment of cutting and stimulating the cord of a frog while its circulation is observed under the microscope.

THE REGULATION OF LOCAL BLOOD SUPPLY.

The various organs of the body require an increase of blood supply during their period of activity and a lesser quantity in the intervals between.

Stimulation of sympathetic nerve branches supplying any area nearly always produces contraction of the vessels in that area.

Efferent *vaso-dilator* as distinguished from *vaso-constrictor* nerves.

The vasomotor effect of stimulating the peripheral end of the mylo-hyoid nerve in the frog.

The effect of stimulating the peripheral end of the chorda tympani upon the circulation in the sub-maxillary gland of the dog.

The physiology of blushing.

The functional vaso-motor changes of erectile tissues.

The changes in the circulation of a vascular area on stimulating its vaso-dilator nerve: The increased calibre of the arterioles; the more rapid blood current; the flow of red blood through the veins; the venous pulse.

The evidence for the presence in the medulla of a double vaso-motor centre, one part sending out vaso-constrictor nerves, the other part supplying vaso-dilator nerves. When one organ receives more or less blood than usual, there must be an alteration of vaso-motor tone in the blood vessels of other districts in order that the mean blood pressure shall remain constant.

The influence of temperature and mechanical disturbances on vaso-motor activity.

Gradual recovery of vascular tone in any area after cutting off its vaso-motor nerves.

THE REFLEX EXCITEMENT OF THE VASO-MOTOR CENTRES.

Stimulation of the central end of nearly any sensory nerve produces general reflex vaso-motor constriction and a consequent rise of blood pressure.

The function of the *depressor* nerve, which in the cat and rabbit finds its way to the heart in a path independent of the vagus. The depressor is an afferent nerve; when divided stimulation of its central end brings about a fall of blood pressure without marked change in the pulse rate.

The reflex dilatation of the vessels in a rabbit's ear through stimulation of the great auricular nerve.

The reflex dilatation of the blood vessels of glands due to the stimulating effect of food upon the appropriate mucous membranes.

Remembering that arterial pressure is the driving force of the blood, consider the difference of physiological effect between rapidly drawing a certain amount of blood from an artery and from a vein.

THE LYMPHATIC VESSELS AND THE FLOW OF LYMPH.

Two modes of origen of lymphatic vessels;—*plexiform* and *lacunar*.

The relative size and direction of lymph and blood capillaries.

The thin vein like walls of lymphatic vessels; their numerous valves.

The *stomata* of serous membranes.

Every tissue element probably lies in a lymphatic space from which fluid rapidly reaches lymphatic channels.

The direction of flow in the lpmphatic vessels.

Influences modifying the flow of lymph;—muscular action; position of the body; respiratory movement. Flow from the opened thoracic duct of a dog.

The lymphatic hearts of birds, reptiles and batrachians.

Difference between lymph and chyle.

Lymphatic glands; their position, structure and function.

The general purpose and cause of the existence of lymph.

DEMONSTRATIONS.

Comparison of the elasticity of arteries and veins.

The valves in the veins.

Dissection of a sheep's heart.

Artificial circulation through a sheeps heart.

The movement of needles in the mammalian heart.

The beat of the isolated heart with an artificial supply of blood.

The influence upon the beat, of valuable pressures; of temperature changes; of various drugs.

The rhythm of beat in the isolated heart of the frog.

The beat of the pigeon's heart directly observed.

The behavior of the ganglion free apex of the frog's heart.

Vagus inhibition of the heart beat in a frog.

The minor arterial schema.

Weber's schema.

Comparison of blood pressures in the carotid and femoral arteries of mammal. Effect on the blood pressure of vagus stimulation. The graphic method of recording physiological observations.

Comparison of the blood pressure and its fluctuations in the femoral vein and femoral artery.

The effect upon blood pressure of stimulating the depressor nerve.

The effect upon blood pressure of cutting, and then stimulating the spinal cord.

X. THE PHYSIOLOGY OF SECRETION.

All the phenomena of secretion probably depend in the end for their occurrence on the physical laws of diffusion and filtration.

The nature of the laws regulating the diffusion and filtration of fluids and of gases.

Simple applications of the laws of diffusion in the living body. The production of diarrhœa by the presence of magnesium salts in the intestine. The interchange of matter between the lymph and the blood and the relation of the animal cell to the process. The gas exchange in the lungs.

Secretion is not simply a process of diffusion and filtration through dead membranes. The diffusion membrane of secretion is *alive.*

In the simplest form of true secretion certain substances are selected by and passed through the secreting membrane. But most secreted fluids contain specific matters which have been produced by the vital activity of the secretory cells.

The typical secretory animal membrane: (1) the secretory cell; (2) the basement membrane; (3) the capillary network.

The modification of the typical secretory membrane into *glands.*

Various forms of glands: tubular and racemose glands.

The parts of a gland: the duct; the acinus or alveolus.

The circulation in glandular tissue.

Enzym. *Mucous* and *albuminous* glands.

THE PHENOMENA OF SECRETION AS DETERMINED IN THE SUB-MAXILLARY GLAND.

The nerve supply of the gland, and the processes of normal secretion.

THE CHEMICAL CONSTITUTION OF SALIVA.

The proportions of water, salts and organic matters. The relative diffusibility of the constituents. The *specific* bodies of the secretion.

THE CHANGES PRODUCED IN THE SUB-MAXILLARY GLAND BY STIMULATING THE PERIPHERAL END OF THE *CHORDA TYMPANI* NERVE.

The dilation of the blood vessels; the venous pulse and red blood in the veins. Vaso-dilator nerves.

The volume of fluid continuously secreted may exceed that of the gland; the fluid could therefore not have been all stored in the resting gland, but must have come from the blood during the stimulation.

The saliva is not simply filtered from the blood, for the secretion still goes on when the pressure of saliva within the duct exceeds that of the blood in the artery of the gland.

Fibres of the *chorda tympani* must control the secretory activity of the gland cells; for, after poisoning with atropin, stimulation of the *chorda* still produces vasomotor dilatation in the gland but causes no secretion.

The antagonistic actions of *atropin* and *pilocarpine.*

The watery fluid of the secretion must have been contained in, and actively forced out of the gland cells.

The secretion obtained by artificial stimulation from the gland of a decapitated animal.

The chief volume of the secretion consists of the easily filtered and diffusible water with salts in solution.

The volume of fluid secreted in a given time does not markedly diminish during a series of stimulations.

The organic matters of the saliva are not readily diffusible.

The organic matters decrease in quantity as secretion progresses. They are probably made by and stored up within the gland cells.

NERVES WHICH REGULATE THE CHEMICAL NATURE OF THE GLAND CELL SUBSTANCE.

When the sympathetic nerve supplying the sub-maxillary gland of the dog is stimulated, the blood vessels of the gland contract and the amount of secretion is insignificant. But after previous excitement of the sympathetic, stimulation of the *chorda tympani* causes a secretion much richer in organic matters than otherwise would be the case.

Stimulation of the peripheral end of the nerve of Jacobson in the dog produces an abundant secretion from the parotid gland.

Stimulation of the peripheral end of the sympathetic supplying the parotid gland of the dog causes no secretion, but greatly increases the organic content of the secretion produced by subsequent stimulation of the nerve of Jacobson.

Nerves of three distinct physiological varieties can be shown to take part in secretion: (1) *Vaso-motor* nerves, which regulate the calibre of the blood vessels; (2) *secretory* nerves, which bring about the active diffusion of water and salts through the gland cells; (3) *trophic* nerves, which produce chemical changes in the gland substance giving rise to more soluble organic matters in it.

THE HISTOLOGICAL CHANGES OF THE SALIVARY GLANDS IN SECRETION.

Comparison of the appearance and reaction toward staining reagents of a resting sub-maxillary gland with one which has abundantly secreted.

Comparison of the histological characters of the parotid gland before and after stimulation of the sympathetic nerve.

The paralytic secretion of saliva.

The theory of secretion suggested by the facts that have been advanced.

THE ABSORPTION OF MATTER INTO THE BODY.

Absorption into the tissues is probably chiefly a process of simple diffusion.

Absorption by the skin.

Absorption by the lungs.

Absorption in the alimentary canal. The preparation in digestion of food matters for absorption. The absorption of fats.

The influence of the nervous system in the process of absorption.

DEMONSTRATIONS.

Stimulation of the *chorda tympani.*

Comparison of the pressure of saliva in the gland duct with that of the blood in the femoral artery.

The action of atropin and of pilocarpin on the gland.

XI. THE VARIETIES AND FUNCTIONS OF INGESTA.

The body must depend upon food matters for the maintenance of its structure and as the source of its energy. The nature of the alimentary substances which might be supposed most readily to fulfill these functions.

The loss of energy to the food in the body.

The source of energy of plant life.

The different kinds and chemical composition of the substances entering into food stuffs: proteids; albuminoids; fats; carbo-hydrates; salts and water; condiments, etc.

The physical and chemical characters, and chemical reactions of the various kinds of alimentary substances.

Proteids form the only class of foods which can probably alone maintain life; but the normal diet contains all the different kinds of food matter.

The history of the various food stuffs in the body, and the form under which they appear in the *egesta.*

Liebig's classification of foods into *plastic* and *respiratory.* Objections to this division.

CLASSIFICATION OF INGESTA.

INGESTA:

- Foods: Supply material for the formation and restoration of tissues. Supply the energy for the construction and activity of the body.
- Force regulators: Do not as such form a part of the living tissues, but are media necessary to their activity. A second class of them acts as a collection of stimulating substances which produce effects out of proportion to the amount of material employed.

Any ingested substance is not restricted in its function to one of the above classes, but may probably at the same time supply energy and tissue material to the body, and serve as a force regulator to the activities of the body.

The two kinds of force regulators represented by a saline solution and a condiment.

The usefulness of cooking.

DEMONSTRATIONS.

The chemical reactions of proteids.

The chemical reactions of fats.

The chemical reactions of starch, dextrin, glycogen and glucose.

XII. DIGESTION; AND THE ACTIVITIES AND STRUCTURE OF THE PARTS INVOLVED IN IT.

THE STRUCTURE AND ARRANGEMENT OF THE MOUTH PARTS.

The anatomy of the buccal cavity and parts in connection with it. The sub-maxillary, the parotid and the lingual glands and their openings.

Structure of the buccal mucous membrane.

The tongue; its muscles, nerves and papillæ.

The teeth; the two sets of permanent and milk teeth; the

number in each. The shape and parts of the various teeth. The *Crusta petrosa; dentine; enamel.*

THE PHYSIOLOGY OF SALIVA.

Saliva as found in the mouth is the mixed product of the three pairs of salivary glands, of the glands of the tongue and adjacent parts, and of the buccal epithelium.

The physical and chemical characters of saliva.

The solid bodies found in saliva; the food detritus; epithelium cells; "salivary corpuscles."

The function of saliva in assisting deglutition.

The physiological process of secretion and influences modifying it. "Watering" of the mouth; the "rice ordeal." The normal reflex.

Quantity of saliva secreted.

THE DIASTATIC ACTION OF SALIVA.

The conversion of starch into sugar under the action of saliva. The chemical change consists in the addition of a molecule of water to one of starch.

The influence of temperature on the rapidity of the diastatic action.

Exposure to the temperature of boiling water destroys the diastatic power of saliva. The action is arrested in a medium containing as much as 0.1 HCl, and strong alkalis destroy the body in the saliva which produces the change.

The amount of starch which may be changed into sugar bears no definite relation to the amount of saliva employed. The diastatic power of the saliva does not seem to decrease proportionately to the extent of the change which it brings about.

The diastatic action of saliva is due to the presence in it of an *animal ferment*, *Ptyalin*, which is probably an organic but non-proteid product of the activity of the salivary glands.

The distinctive characters of ferments. Organized and unorganized ferments.

The special characters of the saliva obtained from different glands.

THE PROCESS OF DEGLUTITION.

The masticated mouthful of food is brought together in a heap upon the back of the tongue, and thence, by a complicated series of coördinated movements, is transferred to the stomach.

The protective movements of the respiratory apparatus, and the function of the epiglottis.

The process of deglutition may be divided into three stages: (1) while the food is still within the mouth, the movement is purely voluntary and may be slow or rapid. (2) When the food reaches the common buccal and respiratory chamber of the pharynx, the movement is nearly purely reflex, or involuntary, and is then most rapid. (3) When the food reaches the œsophagus its movement is again slower and quite involuntary, and the mouthful is carried by a peristaltic contraction to the stomach.

The nervous mechanisms involved in the swallowing movement. The centre in the *medulla.*

The histological structure of the œsophagus.

The mechanisms and processes involved in *vomiting.*

The stimulus to the movement may be either peripheral or central. Majendie's experiment. Nausea.

THE STRUCTURE AND PHYSIOLOGY OF THE STOMACH.

THE ANATOMY AND HISTOLOGY OF THE STOMACH.

The shape, anatomical connections, and nervous and vascular supply of the stomach. The *fundus.*

The empty stomach is always contracted.

The three coats of the stomach: (1) muscular; (2) areolar; (3) mucous.

The muscular coat is composed of unstriated tissue. Its layers of longitudinal, oblique and circular fibres.

The cardiac and pyloric sphincters. The pyloric "valve."

The areolar coat. Division of blood-vessels in it.

The mucous membrane. The *rugæ* and their cause.

The shape and cellular elements of the glands of the mucous membrane. The difference between the glands of the pyloric and other regions of the stomach. The blood and lymph vessels of the mucous membrane.

The nerve cells within the stomach wall.

THE GASTRIC JUICE AND ITS SECRETION.

The fluid obtained from the stomach of a dog with gastric fistula by means of electrical, mechanical or chemical stimulation of the mucous membrane. Dilute alkalis readily excite the secretion.

The quantity of gastric juice secreted in 24 hours.

THE CHEMISTRY OF THE GASTRIC JUICE.

The gastric juice of the dog contains about 0.45 p. c. solid matter, of which half is inorganic saline, and half organic matter, the ferment *pepsin*, mucus, etc. The reaction is always acid, due to the presence of free HCl. Lactic and butyric acids, which are frequently present, are probably due to fermentations of the food matter, and not to the secretory activity of the stomach. The amount of free HCl is about 0.2 p. c. of that of the normal juice.

THE DIGESTIVE POWERS OF THE GASTRIC JUICE.

The digestive powers of the gastric juice are due to the action of a ferment *pepsin*, which is made in and secreted by the cells of the stomach glands. Pepsin is probably an organic but non-proteid body.

The presence of free acid is necessary to the action of gastric juice. The power of the juice is destroyed by the temperature of boiling water. The rapidity of digestion depends upon the temperature.

On *starch* the gastric juice has no effect, though it may set free starch grains which are held together by proteid substances.

On *sugars* the gastric juice has no effect; though there appears to be a ferment in the mucus, which is secreted by the epithelium covering the mucous membrane, which has the

power of converting *cane* into *grape* sugar. An excess of cane sugar in the food causes an increased secretion of mucus.

The mechanical function of the mucus as a cleanser of the alimentary canal.

On *fats* the gastric juice has no effect, though they are set free by the solution of the proteid and gelatiniferous portion of their cell envelopes.

Albuminoid substances are dissolved by the gastric juice.

Such *mineral salts* as are soluble in dilute acids are dissolved by gastric juice.

The chief digestive power of the gastric juice consists in its decomposition of *proteids* by which they are converted into soluble, diffusible substances called *peptones.*

Experiments upon the digestive power of gastric juice may be carried out either with natural or artificial juice.

Artificial gastric juice may be prepared by extracting the minced mucous membrane of the stomach, (1) with water, (2) with dilute hydrochloric acid (0.2 p. c.), (3) with glycerine, (4) or with glycerine after standing under strong alcohol.

Gastric juice acts most rapidly at about the body temperature, and is inert at 0°C.

The presence of free acid, best HCl 0.2 p. c., is necessary to the activity of the juice.

The acid is used up in digestion and gradually disappears from an artificial solution.

The ferment, pepsin, does not appear to be used up in digestion.

Evidence that pepsin is formed by changes in the stomach glands after death; that it is made during secretion and not stored up in the cells.

The pro-ferment, *pepsinogen.*

The activity of the gastric juice is greatly hindered by the accumulation of the products of digestion.

The histological changes which the gastric gland cells undergo in digestion.

The changes as to granulation which digestive cells in general go through in their activity.

The functions of the different kinds of cells of the stomach glands. The relation of the glands in the pyloric part of the stomach to those in other regions of the organ.

THE CHANGES OF PROTEIDS IN GASTRIC DIGESTION.

The characteristic swelling of the proteid substance and its gradual solution.

The formation of soluble albumin, precipitable by boiling.

The formation of *parapeptone* or acid albumin. Dilute acid alone may effect these changes.

The formation of *peptone*. *Dyspeptone.*

Complete and incomplete peptones.

Characters of perfect peptones: peptones are soluble in water, but are not precipitated by boiling; they answer the chemical tests for proteids; they, unlike other proteids, are readily diffusible. They are not precipitated by strong acetic acid and potassium ferrocyanide, as are the incomplete peptones.

Kühne's theory of the division of proteid substances by gastric digestion into two groups—*Hemi-peptone* and *Anti-peptone.*

The formation of peptones appears to be brought about by a hydration of the proteid.

The milk ferment. Rennet.

THE HISTORY OF THE FOOD WITHIN THE MOUTH AND STOMACH.

The effect of mastication and the mechanical and chemical functions of saliva.

The swallowed saliva excites the flow of gastric juice, as does probably the mere smell of food.

The digestive action of saliva upon starch is not interfered with by the acidity of the gastric juice to the same extent as would be the case in a pure acid of the same strength.

The mechanical and chemical changes of the food in the stomach. The usefulness of thorough mastication. The mechanical dissolution of the fats, starches and proteids. The nature of the movement of food in the stomach. The *chyme.*

The processes of solution, absorption and passage into the intestine.

The rapidity of digestion in the stomach and influence modifying it: nature of the food; method of cooking; state o division; temperature; rate of absorption; the efficiency of the gastric juice and rapidity of its secretion; the energy of movement which mixes the food.

THE MECHANISMS OF SECRETION AND OF MOVEMENT IN THE STOMACH.

The only nerves reaching the stomach are branches from the vagi and the splanchnics.

Normal gastric juice is secreted after division of both sets of nerves. The essential secretory mechanism seems to be local. The food is brought directly into contact with the secretory membrane.

The influence of emotions on secretion.

The normal mucous membrane is flushed during digestion; it becomes pale on cutting through the vagi, and reddens again when the central ends of these nerves are stimulated.

Afferent vaso-motor impulses seem to travel from the stomach along the vagi, while efferent vaso-motor impulses descend to the stomach in the splanchnić fibres.

The nature and cause of the movements of the stomach.

The empty stomach is contracted; the empty intestine is relaxed.

The influence of mechanical distension on movement of the stomach.

The influence of extrinsic nerves.

THE CHANGES WHICH THE FOOD UNDERGOES IN THE INTESTINE, AND THE DIGESTIVE ORGANS INVOLVED IN THEM.

The digestive fluids which are poured into the intestine are all alkaline in reaction and come from three sources: (1) the Pancreas, *pancreatic juice;* (2) the Intestinal Mucous Membrane *succus entericus;* the Liver, *bile.*

THE ANATOMY AND HISTOLOGY OF THE PANCREAS.

The relative position of the openings of the bile and pancreatic ducts into the intestine in man and in other animals.

The lobulated structure of the gland.

The histological appearance of the pancreas. The ducts; the single *acini;* the gland cells, their outer hyaline and inner granular zone.

The phases of histological change which the gland cells undergo in digestion. The observation of the pancreas in a living rabbit.

In general, the granular matter of a resting secretory cell is distributed throughout the whole of the cell; while as a result of activity, the granules are fewer in number and are accumulated round the lumen of the gland on the inner border of the cells.

The difficulty of establishing a permanent pancreatic fistula.

The pancreatic juice begins to flow from a fistula immediately on food being taken; the rate of secretion increases till about the fourth hour, then decreases for an hour, and then increases again, reaching a second maximum at the eighth hour after taking food, afterward declining.

The amount of pancreatic juice secreted in 24 hours.

THE CHARACTERS AND POWERS OF PANCREATIC JUICE.

Normal pancreatic juice is a clear, viscid fluid, frothing when shaken. It has a decided alkaline reaction.

The fluid contains about 8 p. c. solids, consisting of albumin, alkali albumin, leucin and tyrosin, some fats and soaps and a considerable amount of soda carbonate. The presence of leucin, tyrosin and soaps is probably due to digestive changes in the juice after its secretion.

The pancreatic juice is probably the most important of all the digestive fluids. It probably normally contains several distinct kinds of ferment.

The action of the pancreatic juice upon *starch* is similar to that of saliva, but is apparently more powerful.

Neutral *fats* are emulsified by pancreatic juice, and are partly decomposed into glycerine and a fatty acid.

Unlike the gastric juice, pancreatic juice does not dissolve gelatiniferous substances.

On *proteids*, pancreatic juice exercises a powerful solvent action, converting them into *peptones*.

The digestion of proteids does not cease at this stage, but peptones are farther decomposed into two nitrogenous crystalline bodies, *leucin* and *tyrosin*.

The complicated changes undergone by proteids in their digestion; the bye-products formed are alkali-albuminates instead of acid-albuminates as in the case of gastric digestion.

The special proteid ferment of the pancreatic juice is called *trypsin*.

Kühne's theory of the changes undergone by proteids in gastric and pancreatic digestions.

The digestion of proteids by natural or artificial pancreatic juice in an alkaline medium is attended with the formation of *indol*, a substance having an offensive fæcal odor.

Indol is not formed when the digestion is carried on in the presence of salicylic acid. It is probably not a product of digestion, but of the activity of adventitious organized ferments.

A proteid, as fibrin, undergoing pancreatic digestion appears to be gradually corroded and crumbled; it does not swell as when acted on by the gastric juice.

If the pancreatic ferments be exposed to the temperature of boiling water their digestive power is destroyed.

An artificial extract of the pancreas may be made which shall have all the powers of the natural juice.

The extract of the perfectly fresh gland has little or no digestive power.

The fully formed ferment does not exist stored up in the gland cells during life. The living cells do not contain *trypsin* but hold an antecedent to this ferment, called *zymogen*.

Trypsin is quickly formed in the excised pancreas when this is exposed to a warm temperature.

Addition of strong acetic acid rapidly converts zymogen into trypsin, and a powerful digestive fluid can than be made by extracting the gland with a 1 p. c. solution of soda carbonate.

THE RELATION OF THE PROTEID FERMENTS OF THE GASTRIC AND PANCREATIC JUICES.

Gastric juice can digest only in an acid medium. Pancreatic juice digests best in an alkaline fluid, 1 to 2 p. c. soda carbonate, but is still active in a neutral or slightly acid solution.

When pepsin and the pancreatic ferments are mixed together in an acid solution, pepsin acts upon and destroys the trypsin.

THE STRUCTURE OF THE INTESTINE AND THE SECRETION PRODUCED BY ITS GLANDS.

ANATOMY AND HISTOLOGY OF THE INTESTINE.

The arbitrary division of the small intestine into *duodenum*, *jejunum* and *ileum*.

The three coats; *muscular*, *areolar* and *mucous*. The circular and longitudinal muscle fibres.

The nerve plexuses of Auerbach and of Meissner.

The *valvulæ conniventes*.

The *villi* of the small intestine; their capillary and lymph vessels; the layer of muscle cells; the striated borders of the covering epithelium.

The glands of Brunner,

The "crypts" of Lieberkühn.

Peyer's "patches."

The secretion of the intestinal glands, the *Succus Entericus*, is an alkaline fluid having slight proleotytic and amylolytic digestive powers.

THE BILE.

The bile is the secretion of the liver cells. and in the intervals between digestive activity is stored up in the gall bladder.

CHEMICAL AND PHYSICAL CHARACTERS OF BILE.

The bile is decidedly alkaline in reaction.

The green bile of herbivora and the yellow bile of carnivora.

The biliary pigments *biliverdin* and *bilirubin*.

The clay color of the fæces when bile is prevented from entering the intestine.

Pettenkofer's test for bile acids.

The bile salts; *taurocholate* and *glycocholate* of *soda*.

Gmelin's test for bile pigments.

THE PROCESS OF SECRETION AND THE DIGESTIVE FUNCTION OF BILE.

The secretion of the bile increases rapidly after taking food and reaches its maximum in 4 to 10 hours after a meal. The bile, unlike the saliva, is secreted under a pressure much less than that of the blood.

The passage of dilute acid, as of the contents of the stomach, over the intestinal orifice of the bile duct, causes a gush of bile into the intestine occasioned by contraction of the muscles of the gall bladder. This action is purely reflex.

If bile, or a solution of bile salts, be added to a fluid containing the products of gastric digestion, the complete and incomplete peptones in solution are precipitated. Most of the pepsin is carried down mechanically by the precipitate. Excess of bile redissolves the precipitate and the resulting solution is alkaline in reaction.

The precipitation of the dissolved gastric peptones prevents their too rapid progress along the intestine, and removes the pepsin whose action is destructive to trypsin.

Bile has a slight emulsifying power over fats which is much increased when mixed with pancreatic juice.

It probably mechanically assists in the absorption of fats, as these pass more readily through membranes moistened with bile.

Bile may furnish alkali for the formation of soaps in digestion.

The amount of bile secreted in 24 hours.

The effect of withdrawing bile from the body.

The history of the food in the small intestine. The *chyle.*

ABSORPTION FROM THE SMALL INTESTINE.

The diffusion of liquids. The absorption of fats.

The pumping action of the villi which assists absorption.

The diffusion of water through the wall of the small intestine is about equal in both directions, for the contents of the ileum are as fluid as those of the duodenum. The action of purges.

The mucous membrane of the large intestine is crowded with tubular glands but supports no villi.

The contents of the large intestine rapidly lose water and become dry. They become acid in reaction from the products of intrinsic fermentation. The cæcal digestion of herbivorous animals.

The gases found in the large intestine:—CO_2, N, CH_4, H, SH_2.

The chemistry of the fæces.

The function of mucus as a cleanser of the alimentary canal.

THE MOVEMENTS OF THE INTESTINE.

Fibres from the vagi and splanchnics unite the intestine with the brain.

The peristaltic contraction of the excised intestine.

The normal movements of the intestine and their stimulus.

DEMONSTRATIONS.

The conversion of starch into sugar by saliva; influence of temperature.

The effect upon its amylolytic power of boiling saliva.

The reaction and digestive power of natural gastric juice.

Digestion of proteids with artificial gastric juice. The in-

fluence of the state of division of the proteid; the acidity of the juice; the temperature.

Effect of boiling the juice.

Products and bye-products formed during proteid digestion.

The characters, solubility and diffusibility, of perfect peptones.

Pancreatic digestion; of fats; of starch; of proteids. The formation of leucin and tyrosin. The formation of *indol*.

Pancreatic digestion without formation of indol.

Bile; the acid test of Pettenkofer.

Gmelin's test for bile pigments.

The precipitation and resolution by bile of gastric peptones.

The emulsion of oil in bile and pancreatic juice.

The peristaltic movement of the intestines.

The demonstration of the lacteals after their natural injection with chyle.

XIII. THE RESPIRATION.

THE RESPIRATORY MECHANISM AND ITS FUNCTIONS.

The object of the respiration is the removal from the body of waste products of tissue change and the renewal of oxygen to the tissues.

This interchange of matter is brought about by the process of *diffusion.*

The function of respiratory movement is to hasten the process of diffusion.

The modification of the respiratory apparatus in different animals. Respiration in an *amœba;* in a marine *worm;* in a *fish;* in an *insect;* in a *frog;* in a *mammal.*

THE STRUCTURE OF THE RESPIRATORY ORGANS IN MAN.

The trachea and bronchi; the incomplete cartilaginous rings; the mucous glands; the ciliated epithelium.

The lungs; the lung alveoli; the air cells and their flattened lining epithelium; the capillary circulation in the lung.

Comparison of the lungs of the batrachian, reptile and mammal.

The muscular and elastic tissue of the lung.

The topographical relations of the lungs. The pleura.

THE MOVEMENTS OF RESPIRATION.

The lungs are extremely elastic and extensible. They are but semi-distended in the thorax. The pressure exerted by the elasticity of the lungs in man is about that of a column of mercury five millimetres high.

The atmospheric pressure upon the inside of the lungs keeps them distended while in the closed chest.

When the chest cavity is enlarged in inspiration the atmospheric pressure causes the lungs to fill the new space; and

when the cavity becomes smaller in expiration the elasticity of the lung substance causes a corresponding diminution in the bulk of the lungs.

Demonstration on an artificial diagram and on a rabbit of the effects of the respiratory movements upon the contents of the chest.

In ordinary breathing, inspiration only involves muscular effort, the expiration being performed by the elastic reaction of the parts.

The cavity of the chest is increased vertically by the contraction of the muscle of the diaphragm. The effect of violent contraction of the diaphagm upon the lower ribs and upon the abdominal viscera.

The movements of the ribs and sternum in respiration.

The *external* intercostals, the *scaleni* and the *levatores costarum* are the elevators of the ribs in ordinary inspiration.

In laboured inspiration the following muscles are also called into play: *Serratus magnus*, *pectoralis minor*, *pectoralis major*, *latissimus dorsi*, *serratus posticus superior*, *serratus posticus inferior*, *quadratus lumborum*, *sacro-lumbalis*.

The internal intercostals are probably muscles of ordinary expiration.

In laboured expiration the abdominal muscles are the chief active agents.

The action of the intercostal muscles as illustrated on Hamberger's *schema*.

In the human species costal respiration is relatively most marked in the female, abdominal respiration in the male.

The movements of the face and larynx in respiration.

The rhythm of respiration.

THE QUANTITY OF AIR IN THE LUNGS AND ITS VARIATION.

After the most violent expiration the lungs still contain about 100 cubic inches air, called the *residual* air. At the end of an *ordinary* expiration the lungs contain an additional 100 cubic inches of *supplemental* air. Thus there are 200 cubic

inches of *stationary* air which in ordinary breathing never leave the chest. In ordinary inspiration an additional 30 cubic inches of *tidal* air are drawn in. By a forced inspiration there may still be added about 98 cubic inches of *complemental* air. The full capacity of the lungs then is 328 cubic inches; the *vital capacity* the amount of air capable of being taken in after the most powerful expiration, is 228 cubic inches. These capacities are estimated from the lungs of a man of medium size.

The process of gas interchange in the lungs under these conditions.

The quantity of air breathed daily.

The effect of respiration upon the movement of blood and lymph.

THE CHANGES OF AIR IN RESPIRATION.

The air expired is nearly always warmer than that inspired.

The air expired is nearly saturated with moisture.

	Oxygen.	Nitrogen.	Carbonic acid.
Pure dried air contains in 100 vols.	20.81	79.15	.04
Expired air contains in 100 vols	16.033	79.557	4.38

The expired air also contains small but important quantities of volatile organic matters.

The volume and weight of oxygen absorbed and carbonic acid given off in a day.

Owing to its higher temperature and contained watery vapour the volume of air expired is greater than that inspired; but when dried and measured at the same temperature the air inspired is found to have diminished in bulk, having lost a greater volume of oxygen than it has gained of carbonic acid in respiration.

Ventilation. The hurtful qualities of air which has been respired are due not so much to its carbonic acid as to the animal matter contained in it.

THE CHANGES UNDERGONE BY THE BLOOD IN THE LUNGS.

The losses and gains of the blood in the lungs.

The difference in color belween the venous and arterial blood.

When exposed to a vacuum 100 vols. blood give off about 72 vols. gas, measured at O°C. and 750 millimetres pressure.

	Oxygen.	Carbonic acid.	Nit'og'n.
100 vols. Arterial blood give	20	50	2
100 vols. Venous blood give	10	60	2

The color of the blood of an asphyxiated animal.

The color of the blood is due to the haemoglobin contained in the red corpuscles.

Oxyhæmoglobin and reduced-hæmoglobin. Hæmoglobin crystals.

The amount of gas given off to a vacuum by blood is greatly in excess of that which could be obtained from an equal volume of blood serum.

The laws which govern the absorption of gases by liquids.

The explanation of the large quantity of gas found in blood is the chemical union of the oxygen with the hæmoglobin.

The combination of oxygen with hæmoglobin is not a stable one, but the gas is given off when the partial pressure of oxygen upon the blood falls below one inch of mercury.

Comparison of the partial pressures of gases in the lung alveoli and in the blood.

The carbonic acid of the blood exists chiefly in loose chemical combination with substances in the plasma.

The respiration of the tissues. The same laws determine the gas interchange in the tissues as in the lungs.

The ratio of the amount of oxygen absorbed and of carbonic acid given off by the tissues in a certain time is not constant. During the day more oxygen is given off in carbonic acid than is taken up in the same time; during the night the proportions are reversed. The same relation holds for periods of activity and of rest.

The amount of oxygen taken into the blood depends not upon the amount supplied to the lungs but upon the amount which has been used by the tissues. The hæmoglobin of arterial blood is normally nearly or quite saturated with oxygen.

The oxidations of the body occur not in the blood but in the tissues.

THE NERVOUS MECHANISM OF THE RESPIRATION.

The mixed voluntary and involuntary characters of the respiratory movements.

The respiratory centre in the medulla oblongata. Instant cessation of respiratory movement follows destruction of this centre.

The phrenic nerves spring from the spinal cord at about the level of the 4th pair of cervical nerves; the intercostal nerves leave the cord throughout the dorsal region.

The coördination of the various respiratory movements.

The effect upon the movement of cutting a nerve supplying any part of the respiratory apparatus.

THE CONDITIONS UNDER WHICH THE RESPIRATORY CENTRE ACTS.

The movements of respiration are remarkably susceptible to modification under the influence of stimuli foreign to their nervous centre; effect of a dash of cold water; effect of emotions.

When any single efferent respiratory nerve is cut the part supplied by it remains quiescent; and when the spinal cord is divided below the medulla the failure in the income of oxygen is accompanied by an exalted action of the respiratory centre as shown by the more powerful action of the remaining respiratory movements of the mouth parts, though these are inefficient to aërate the blood.

When the vagi are divided on each side of the neck the respiratory movements become slower and deeper, but do not cease.

When the central end of the cut vagus is gently stimulated the respiration is quickened, and it may be so hastened that the respirations are fused together and the muscles come to a tetanic standstill in the phase of inspiration.

The same is true, but to a slighter extent, of the inferior laryngeal nerve.

It is not improbable that the mere mechanical conditions of the lungs in the phases of expiration and inspiration excite the respective movements of inspiration and expiration.

It is clear, then, that the respiratery centre is under the modifying control of stimuli proceeding to it along afferent nerves. But that the essential activity of the centre is quite independent of any stimulus reaching it from without.

THE EXCITING CAUSE OF THE RESPIRATORY MOVEMENT.

The action of the respiratory centre is determined by the condition of the blood supplying it.

The centre is made active by venous blood but is not excited by arterial blood.

It appears to be the want of oxygen and not the excess of carbonic acid which stimulates the centre, as shown by the respiratory disturbance of an animal breathing in an atmosphere of hydrogen.

The activity of the respiratory centre is determined by the direct of influence of the blood upon it, irrespective of the condition of the blood in other parts of the body.

We may suppose that the activity of the respiratory centre causes an accumulation of stimulating waste products in it, and that the oxygen supplied by arterial blood combines with and renders these inert.

The change of normal respiratory rhythm into that of *dyspnœa.*

The breathing of dyspnœa owes its character to lack of oxygen. In ordinary dyspnœa the breathing is deeper than usual and the rhythm generally slower, as after section of the phrenic nerves. In the dyspnœa of asthma, however, the respirations are quicker and rather less deep than usual.

Physiolgical *apnœa* is the condition of rest in the respiratory centre due to excessive respiration.

THE RHYTHMIC ACTION OF THE RESPIRATORY CENTRE.

The respiratory discharge is probably the resultant of two forces, one exciting to discharge and the other resisting it.

Many mechanical analogies can be cited showing how, under similar conditions, rhythmic action is brought about.

The waste products of tissue change in the respiratory centre are probably the stimuli to its discharge.

The function of the afferent respiratory nerves is probably to either increase or diminish the exciting as compared with the resisting force in in the centre.

The *resistance theory.*

The double nature of the respiratory centre; the *inspiratory* centre; the *expiratory* centre.

The phenomena and means of production of *asphyxia.*

Poisoning by carbonic oxide.

Modified respiratory movements:—*yawning*; *sighing*; *coughing; hiccough; sneezing; laughing; sobbing.*

DEMONSTRATIONS.

Diagram illustrating the effect upon lungs and heart of the respiratory movements.

Hamberger's schema illustrating the action of the intercostal muscles.

Proof of the absorption of oxygen and the production of carbonic acid in respiration.

The respiratory rhythm, and the phenomena of *dyspnœa*, *apnœa* and *asphyxia.*

The effect of stimulating the afferent respiratory nerves.

Puncture of the *nœud vital.*

XIV. THE SKIN AND ITS APPENDAGES.

The skin consists of two layers, an outer cellular layer the *epidermis* or *cuticle*, and an inner layer composed chiefly of connective tissue, the *dermis*, *cutis vera* or *corium.*

The hairs and nails are local modifications of the epidermis.

HISTOLOGICAL STRUCTURE OF THE SKIN AND ITS APPENDAGES.

The *dermis:*—its structural tissue; the papillæ—their arrangement into rows; its blood vessels; tactile corpuscles and Pacinian bodies; groups of fat cells.

The epidermis :—soft and horny epidermis; the lower layer of perpendicular cells; the pigmented cells of dark races; nerve endings; cause of the external ridges.

The nails.

The sudoriparous or sweat glands; the spiral opening and the coiled inner termination.

Hair; the papilla and hair follicle; the hair muscles; the erectile tissue about the base of sensory hairs.

The sebaceous or oil glands.

THE SECRETION OF THE SWEAT GLANDS.

The functions of the perspiration are to remove waste matters from the body, and to serve as a regulator of the body temperature.

The conditions determining the amount of perspiration :—temperature; moisture of the air; exercise; nature of food.

The quantity of sweat secreted in twenty-four hours.

Sensible and insensible perspiration.

The sweat is acid in reaction and owes its odour to volatile oils.

Composition of the perspiration;—water; fatty acids; sodium chloride; urea.

THE MECHANISM OF THE SWEAT SECRETION.

An increased flow of blood to the skin usually attends the production of perspiration, but is not the cause of it. The dry skin of fevered patients.

The emotion of terror may cause sweating from a pale skin

Sweat is produced by the activity of the cells of the sudoriparous glands under control of the nervous system.

Section of the sciatic nerve of the cat causes reddening of the balls of the feet but no sweating. Stimulation of the peripheral end of the nerve causes the secretion to appear upon the balls of the feet, even of a freshly amputated leg.

Sweating as a reflex action.

Pilocarpin excites to activity the sweat glands; atropin abolishes their functions.

Absorption by the skin.

The secretion of the sebaceous glands.

XV. THE KIDNEYS AND THEIR SECRETION.

GROSS STRUCTURE OF THE KIDNEY.

The capsule surrounding and vessels entering the kidney.

The *hilus; pelvis; calices.* The cortical and medullary portions of the opened kidney; the papillæ. The pyramids of Malpighi and of Ferrein.

MICROSCOPIC STRUCTURE OF THE KIDNEY.

The uriniferous tubules; the Malpighian corpuscles; the loops of Henle; the convoluted and collecting parts of the tubules.

The lining cells peculiar to different parts of the tubules.

The blood supply of the kidney; the *glomeruli.*

THE URINE.

The quantity secreted in 24 hours varies from 40 to 60 fluid ounces.

The complementary activity of skin and kidneys.

The color, reaction and specific gravity of urine.

The variation of color and specific gravity.

THE AMOUNT AND COMPOSITION OF URINE PASSED BY A MEDIUM SIZED MAN IN TWENTY-FOUR HOURS. (Foster's Physiology).

Water..1500.000 grammes

Total solids.. 72.000 grammes

Urea................	33.180 grammes	Chlorine..........	7.000 grammes
Uric acid.........	.555 grammes	Ammonia.........	.770 grammes
Hippuric acid....	.400 grammes	Potassium........	2.500 grammes
Pigment, fats, &c	10.000 grammes	Sodium............	11.090 grammes
Sulphuric acid..	2.012 grammes	Calcium...........	.260 grammes
Phosphoric acid	3.164 grammes	Magnesium......	.207 grammes

The general nature and origin of the various substances found in the urine.

THE SECRETORY MECHANISM.

The uriniferous tubule consist of two parts each of which probably serves special purposes. The thin walled capsules round the glomeruli probably allow rapid filtration of water and salts through them, while the cells lining the tubules proper have no doubt the function of active secretion.

INFLUENCES DETERMINING THE AMOUNT OF THE SECRETION.

Increased flow of blood to the kidney, bringing about a high blood pressure in the glomeruli, increases the amount of urine secreted. This may follow general rise of blood pressure or local dilation of the renal arteries.

The effect of cold in constricting the vessels of the skin is to raise general blood pressure.

Dilution of the blood increases the secretion.

Stoppage of the secretion after section of the spinal cord.

THE SECRETORY EPITHELIUM OF THE TUBULES.

It is probable that the cells lining the tubules have the power of active secretion independent of blood flow.

The passage of indigo-carmine through the renal cells.

The injection of urea or urates excites the flow of urine.

The process of secretion as studied in the kidney of an amphibian.

The distinction between selection by the kidney cells of urea from the blood and the manufacture of it by them from certain antecedents.

The evidences as to the part played by the kidney cells in the elimination of urea.

The physiology of micturition.

DEMONSTRATIONS.

The secretion as collected from the ureter; the effect of blood pressure upon the rate of secretion.

The effect of dilution of the blood and of the addition of urea to it, upon the rate of secretion.

XVI. THE PHYSIOLOGY OF NUTRITION.

The subject of nutrition is a chemical study, and it has to do with the changes which matters entering the living body undergo there.

The waste matters of the body are at a lower chemical potential than the food matters, and it is believed that this energy difference is exactly represented by the vital force of the animal.

The food matter absorbed into the body does not necessarily fall directly to the chemical standpoint of the wastes, but it probably most often reaches the condition of the latter after passing through a series of synthetic as well as analytic changes.

The products of digestion must be worked over by living tissues before they form part of the normal blood.

THE STRUCTURE OF THE LIVER.

The liver is the chief seat of changes undergone by the digested food in its preparation for the tissues. The blood coming from this organ is probably the warmest in the body. In the embryo the liver is proportionately large, and is there probably the seat of the formation of blood corpuscles. In many lower animals the liver secretes digestive juices; among mammals its only secretion, and that is partly an excretion, is bile.

Most of the blood of the liver is collected from the viscera into its portal circulation, from which the circulation in the hepatic arteries and capillaries is distinct.

The division of the liver substance into lobules.

Glisson's capsule and the three interlobular vessels, the hepatic artery, the portal vein and the bile duct, inclosed by it. The intra-lobular, the sub-lobular and the hepatic veins.

The hepatic cells; granular polyhedral bodies without cell membrane, often containing globules of fat and masses of glycogen.

The histological changes of the hepatic cells during digestion.

The origin of the bile ducts between the liver cells.

CONSTRUCTIVE METABOLISM OF THE BODY.

THE PART PLAYED BY THE LIVER IN THE HISTORY OF GLYCOGEN.

The liver is preëminently the organ of those chemical changes in the body which do not involve the formation or disintegration of permanent tissues.

Glycogen may be found in considerable quantity in the liver cells of normal animals; it may also be extracted in small amounts from probably any living tissue.

When food is withheld from an animal the quantity of glycogen in its liver begins immediately to diminish, and finally probably completely disappears.

If food be again given, the accumulation of glycogen in the liver proceeds rapidly till it has reached its former amount. Carbohydrate foods are particularly favorable to the laying up of glycogen by the liver.

The glycogen is no doubt constructed by the activity of the liver cells out of the food matter coming from the digestive tract.

When the liver is removed from the body and allowed to lie in a warm place, after a time it is found that the glycogen has disappeared and that sugar has been produced in its place. If the liver be boiled while quite fresh, it is found to contain much glycogen but little or no sugar. When the liver is removed from the body its store of glycogen is turned into sugar by the action of a ferment, probably produced within the liver cells.

It is probable that the glycogenetic function of the liver consists in the storage within the liver cells of the carbohy-

drate moieties of the food matter in the comparatively insoluble form of glycogen. Under normal conditions this glycogen is transformed into soluble sugar at a certain definite rate, the sugar passing into the general circulation for the supply of the tissues. Through this function of the liver, both the overloading of the tissues with carbohydrate matter at the time of feeding and their suffering for want of it in time of hunger, are prevented.

DIABETES.

Temporary diabetes may be artificially produced in an animal. If a well-fed rabbit be punctured in the vaso-motor region of the medulla the flow of urine will be increased and in one to two hours it will contain considerable sugar, which after a day or two will have disappeared again. If the animal be previously starved so that the liver contains little or no glycogen, the urine after the operation will contain little or no sugar. The sugar found, then, has come from stored up glycogen.

The obscurity of the cause of this diabetes.

Mild and severe forms of natural diabetes and the relation of the nature of the food supply to them.

FORMATION OF FAT IN THE BODY.

The fluctuation in the quantity of fat in the body.

Histological changes in the connective tissue corpuscle which is being converted into a fat cell.

Fatty degeneration of proteid containing tissues.

The ripening of cheese.

The fat of the body may be produced from the metabolism of food matters other than fat. A greater quantity of fat may appear in the milk of a cow than was contained in the food of the animal. The amount of wax produced by bees far exceeds that of the fat found in the saccharine food of the creatures. It has been shown, in one instance, that for every 100 parts of fat in the food of a fattening pig, 472 parts were laid up as fat in the body.

Proteid foods as a source of fat.

The fat of the living body consists of certain average proportions of tri-olein, tri-palmitin and tri-stearin which are unaltered by the variation of the proportions of those substances in the food; therefore the fat of the body is not simply that of the food stored up unchanged.

THE STRUCTURE AND SECRETION OF THE MAMMARY GLANDS.

Each human mammary gland is composed of a number of distinct lobes which are bound together by connective tissue containing much fat. Each lobe is farther divided into smaller and smaller lobules. The ductules of neighboring acini unite, and the ducts, from 15 to 20 in number, of the various lobes thus formed open separately upon the nipple. The ducts are dilated near their external openings so as to form small milk reservoirs. The ducts and the terminal acini are lined by short columnar epithelium.

Fresh milk is alkaline in reaction but may become acid while yet in the gland ducts. Its chemical constituents are,—water; casein, serum albumin; fats; milk sugar; potassium phosphate, calcium phosphate, potassium chloride, magnesium phosphate.

The fatty globules forming the emulsion are surrounded by albuminous envelopes.

Colostrum differs from ordinary milk in being deficient in casein and proportionately rich in albumin.

Milk sugar is readily changed by fermentation into lactic acid which then causes coagulation of the casein.

The protoplasm of the mammary gland cell probably forms all the organic constituents of the milk.

Histological changes in the gland cells during lactation.

The fats of milk are increased by proteid feeding and the amount of milk sugar is not dependent on the carbohydrates eaten.

THE STRUCTURE AND PHYSIOLOGY OF THE SPLEEN.

The structure of the spleen is much like that of a lymphatic gland. The organ consists of a reticular framework of bands of elastic tissue, in the interspaces of which rests the red-brown spleen pulp which consists of a network of branched connective tissue corpuscles, through the interstices of which oozes blood in which are found red corpuscles apparently undergoing destructive metamorphosis. The trabecular substance of the spleen contains much plain muscular tissue. The outer connective tissue coat of the smaller arteries is frequently dilated into small spheroidal bodies which have the structure of lymph follicles, the so-called *Malpighian* corpuscles.

The spleen may be extirpated without danger to the life of the animal. After such an operation there seems to be an increase in the size of the lymphatic glands and in the activity of the medulla of bones.

The spleen increases in size up to about the fifth hour of digestion, and then diminishes again.

The amount of blood passing through the spleen is probably regulated by the action of the muscle fibres found in the trabecular tissue of the organ.

The spleen is probably a seat of the formation of white corpuscles and destruction of red corpuscles of the blood. The peculiar "spleen corpuscles" which contain fragments of red blood disks.

The pulp of the spleen is very rich in so-called extractive matters.

THE ORIGIN OF UREA.

The living tissues are continually being wasted and restored, and the nitrogen of the wastes is nearly all contained in the urea excreted.

Muscular tissue contains kreatin, uric acid and other crystalline nitrogenous bodies, but no urea.

THE RELATION OF THE KIDNEYS TO THE FORMATION OF UREA.

It is probable that the nitrogenous crystalline substances of the muscle are waste products of the tissue and in part antecedents of urea.

There is some reason to believe that the cells of the renal tubules may effect the conversion into urea of certain antecedents of the latter which are found in the blood.

THE RELATION OF PANCREATIC DIGESTION AND OF THE LIVER TO THE FORMATION OF UREA.

The pancreatic digestion of proteids may give rise in the intestine to considerable amounts of leucin and tyrosin. Leucin injected into the alimentary canal reappears as urea in the urine. The liver always contains urea in its substance. It is not improbable that the liver cells turn into urea the leucin produced by excessive proteid digestion in the intestine.

The possible chemical process by which the liver forms urea from leucin, as indicated by the results which follow the ingestion of sarcosin.

Uric acid though less oxidized than urea is probably not an antecedent of the latter. Uric acid replaces the urea in the excrement of birds.

The chemical functions of the liver which are indicated in the elimation of hippuric acid.

STATISTICAL STUDY OF NUTRITION.

The proportion in which the various tissues exist in the body. The relative diminution of the tissues during starvation.

The history of nitrogen excretion in the urine of a starving animal. *Luxus consumption.*

The study of the changes taking place in the body by a comparison of the substances entering it with those coming out of it.

The effect of nitrogenous foods on the chemical processes of the body. *Nitrogen equilibrium.*

The Banting system of dietetics.

The effects of fatty, of carbohydrate food and of gelatine.

The functions of these foods as force regulators.

The effects of salts in the food.

It is probable that the urea excreted has at least two different sources; arising in pretty definite quantities from the nitrogenous tissues, and also coming in fluctuating quantities from the decomposition of proteid matter which never forms part of the general tissues.

The dietetic value of the various food stuffs.

THE NATURE OF THE PROCESSES WHICH GIVE RISE TO THE BODILY ENERGY.

The amount of energy evolved by the body is represented by the difference between the chemical potentials of the food and the waste matter and is wholly unaffected by the manner in which this degradation is brought about.

In every change of matter in the body by which molecules are made more unstable, energy is absorbed; in every change in which the reverse takes place, energy is evolved.

Those movements of the body which involve friction are attended with a loss of heat. The difference between the mechanical energy of the blood in the aorta and in the venæ cavæ must be represented by an equivalent of heat, produced by friction in the blood-vessels. The heat lost by radiation, conduction and evaporation, owes its origin to chemical changes in the body.

The energy set free in the body all reappears either as heat or mechanical energy.

THE ENERGY SUPPLY OF THE BODY.

The amount of energy stored up in the various food matters may be determined in heat unites when these are completely burned.

The direct oxidation of the following, dried at 100° Centigrade:	Gives rise to Gram. degree,	Met.-Kilo.
1 gram Beef-fat	9069	3841
1 gram Arrowroot	3912	1657
1 gram Beef-muscle purified with ether	5103	2161
1 gram Urea	2206	934

Supposing that all the nitrogen of proteid food goes out as urea, 1 gram of dry proteid, such as dried beef-muscle, would give rise to about one-third gram of urea, hence:

	Gram degree,	Met-Kilo.
1 gram Proteid	5103	2161
Less		
⅓ gram Urea	735	331
Available energy of 1 gram of Proteid	4368	1850

(Foster's Physiology).

THE SOURCE OF ENERGY OF MUSCULAR WORK.

It was the belief of Liebig that the non-nitrogenous, or "respiratory," foods were oxidized in the body to maintain its temperature, while the nitrogenous, or "plastic," foods went to form the living tissues and that the functional changes of the latter gave rise to the nitrogen of the egesta.

It is probable that muscular labor does not involve the destruction of the nitrogenous part of the muscle molecule. The amount of nitrogen excreted is not increased by muscular work.

The experiments of Parkes, of Fick and Wislicenus. The experiments of Flint.

The amount of carbonic acid excreted is immediately and greatly increased by muscular work.

The experiments of Pettenkofer and Voit, comparing the oxidations of the body while in a state of rest and at work.

The oxidations of the body occur in the tissues and not in the blood or the lungs. These oxidations are not immediately dependent upon the respiration. Excess of carbonic acid given off during the day and of oxygen absorbed in the night.

The muscle molecule probably consists of an essential nitro-

genous portion capable of adding to itself certain combustible non-nitrogenous matters, which latter, during functional activity, are oxidized and give rise to free energy.

ANIMAL HEAT.

The energy difference between the food and waste matters all reappears as heat in a resting animal. During work, the oxidations of the body and the heat produced are increased.

The muscles, glands and central nervous tissues are the chief seats of heat production in the body.

The mechanical energy of the circulating blood finally reappears as heat.

The body temperature of different animals.

The difference between the temperatures of difference parts of the body and the variation of temperature in the same part.

The blood coming from the liver is the warmest in the body.

THE MAINTENANCE OF A CONSTANT BODY TEMPERATURE.

THE REGULATION OF THE LOSS OF HEAT.

The loss of heat through various chanels is calculated as follows:

In warming fæces and urine.................... 2.5 p. c.
In warming expired air......................... 5.2 p. c..
In evaporating the water of respiration...14.7 p. c.
In conduction, radiation and evaporation by the skin.......................................77.5 p. c.

The means by which the loss of heat through the lungs and skin is controlled.

The perfection of this regulation as shown by the high temperatures which can be borne in a dry atmosphere.

In some hair-covered animals the chief loss of heat is by means of the lungs.

The function of the non-conducting layer of subcutaneous fat.

THE REGULATION OF HEAT PRODUCTION.

The oxidations in the body of a warm-blooded animal are increased by a low surrounding temperature; those of a cold-blooded animal are decreased.

This increased production of heat in warm-blooded animals is probably the result of a reflex action in which the activity of a thermogenic nerve-centre is involved. A curarised animal, or one whose spinal cord has been divided, shows, like a cold-blooded creature, diminished oxidations when the surrounding temperature is lowered.

The action of the thermogenic centre increases the chemical changes of the tissues, leading to an excessive absorption of oxygen and evolution of carbonic acid.

It has been made certain that the loss of heat from the body is under nervous control, chiefly through means of, 1, the vaso-motor centres; 2, the sweat centres; 3, the respiratory centres.

It has been made highly probable that the production of heat is under the nervous control of centres which cause, 1, an increase of heat production; 2, a diminution of heat production. That is, there are probably heat producing and heat inhibitory nerve-centres.

THE INFLUENCE OF THE NERVOVS SYSTEM ON THE NUTRITIVE PROCESSES OF THE BODY.

Many obscure facts point to a nervous regulation of the nutritive processes of the body, but in no instance has such an action been proven. Inflammation of the cornea which follows section of the trigeminal nerve. Pneumonia which succeeds division of the vagi.

It is at present safest to consider that the healthy nutrition of a part depends upon the sum total of its physiological actions rather than on the influence exerted by a special "trophic" nerve.

DEMONSTRATION.

Extraction of glycogen from the fresh liver, and the conversion, by the liver ferment, of glycogen into sugar.

XVII. THE SPINAL CORD.

STRUCTURE OF THE SPINAL CORD AND ACCESSORY PARTS.

The spinal cord is closely invested by the vascular *pia mater* which gives rise to the connective tissue frame-work of the cord.

Outside the *pia mater* is the *arachnoid* membrane, and between the two sheets of tissue is found the cerebro-spinal fluid.

Surrounding the parts just described is a dense membrane, the *dura mater*, which is at points attached to the wall of the neural canal.

The spinal cord is held in position by the spinal nerves entering it, and by ligaments passing from the *pia mater* to the *dura mater*.

The cervical and lumbar enlargements of the cord.

The *cauda equina* and the *filum terminale.*

Each spinal nerve divides into two branches, the anterior and posterior spinal roots, just after entering the neural canal. All the *sensory* fibres of the spinal nerves enter the cord by the *posterior* roots; all the *motor* fibres leave the cord by the *anterior* roots. Each posterior root bears a ganglion near the point of its juncture with the anterior root.

The spinal cord is divided longitudinally on its anterior side by a broad shallow groove, the *anterior median* fissure. Posteriorly the cord is similarly divided by a deeper and narrower *posterior median fissure*, which is filled by a sheet of inflected connective tissue. The two sets of spinal nerve-roots enter the cord along tolerably definite lines, the *lateral fissures.* As marked out by these fissures, the cord may be considered to be made up of a pair of *anterior*, a pair of *lateral* and a pair of *posterior columns.* The posterior columns have further indicated on their surface a narrow *posterior median column.*

The central canal of the spinal cord, lined by cuboidal ciliated epithelium.

Running through the cord is a core of gray matter which has a double crescent shape in cross section.

The nervous matter of the white substance of the cord is composed of medullated nerve fibres; that of the gray substance is made of nerve cells, and nerve fibres chiefly without the fatty sheath.

The variation in form and mass of the gray matter in different parts of the cord. The gelatinous substance in the posterior cornua.

The shape and distribution of the nerve cells and the connection of nerves with them.

The anterior white commissure and the gray commissures.

Most, if not all, the nerve fibres reaching the spinal cord sooner or later enter its gray substance.

The nervous elements of the cord are intimately bound and supported by a connective tissue frame-work. The *neuroglia*.

THE SPINAL CORD AS A CENTRE FOR REFLEX ACTIONS.

The spinal cord contains nervous centres capable of sending out nervous discharges which may stir up complicated, coördinated and adaptive movements.

These movements are never initiated in the cord, but are brought about by impulses reaching the cord from without; that is, they are not *spontaneous*, but reflex in character.

The stimulation of the terminal organs of the afferent nerves is much better adapted for arousing reflexes than the direct stimulation of a nerve trunk.

The nerve cell requires time to cause an efferent nervous discharge after having received an impulse from an afferent nerve. The reflex nerve cell is readily excited to action by a succession of distinct impulses reaching it, but rarely by a single one.

The inhibition of a reflex action may be occasioned by the strong stimulation of any afferent nerve, or by the influence

of nerve centres in the brain or spinal cord other than the reflex centre.

The peculiar movements of a mammal with divided spinal cord.

The spinal cord has no power of *learning* to adapt its activities to new conditions.

In a certain sense the spinal cord may be looked on as a servant of the centres of intelligence which has learned, under their instruction, to carry out alone certain oft repeated actions.

There is no evidence of the spinal cord possessing a conscious intelligence.

THE SPINAL CORD AS A COLLECTION OF AUTOMATIC CENTRES.

One of the functions of the spinal cord, probably, is to act nearly independently by means of special centres whose duty it is to preserve the organic welfare of the body, and whose powers in part are, no doubt, automatic. The nervous control of the sphincter muscles of the body; the sexual centres; muscular tonicity; subsidiary vaso-motor centres.

THE PATHS OF CONDUCTION IN THE SPINAL CORD.

We usually have conscious sensation of the impulses reaching the spinal cord; in such cases the impulses must be transmitted to the brain.

We cannot suppose that all the nerve fibres entering the cord are individually represented by fibres passing to the brain in that organ, for the number of nerve fibres in the spinal cord is not great enough to admit of this.

We may suppose that the fibres, or most of them, from the periphery on the one hand and from the brain on the other, are connected with certain nerve centres in the gray matter of the spinal cord, by whose mediation impulses reaching the cord from many different sources may be sent out of it by a single channel, or conversely. In this sense the nerve cen-

tres of the cord act as relay stations for the transmission of impulses reaching them from any quarter.

The segmental distribution of the gray matter in the cord. The area of gray matter in a cross section of the cord rises and falls with the sectional area of the nerve fibres entering the cord at that level.

It has been attempted to determine the anatomical and physiological grouping of the nerve fibres of the spinal cord, (1) by a study of the direction in which cut fibres degenerate; (2) by the different periods at which various collections of the fibres assume the medullary sheath; (3) by pathological data; (4) by observation of the results following physiological experiment.

All impulses, whether sensory or motor, passing between the brain and the body at large cross the middle line and end in the side opposite to that in which they originated.

This decussation occurs at the level of, and below the pons varolii.

Sensory impulses probably cross to the opposite side lower down in the spinal cord than do the volitional impulses.

Volitional impulses cross most largely in the medulla and travel along the cord in the lateral, and perhaps anterior, columns and enter the nervous centres of the anterior cornua o the gray matter of the cord, whence they emerge in the anterior spinal roots.

Sensory impulses reaching the cord, enter the posterior cornua of its gray matter or its posterior white columns, and soon crossing, proceed to the brain chiefly in the lateral columns.

The most marked results of lateral hemi-section of the spinal cord is a paralysis of voluntary motion and hyperæsthesia on the same side below the injury, with a loss of sensation on the opposite side; probably neither of these effects is complete.

The functions, sensory and motor, which are abolished by a hemi-section of the cord may be gradually recovered without reunion of the divided parts.

Purely tactual, and painful sensory impulses probably pass through the cord along different paths.

The gray matter of the cord can no doubt conduct in any direction the impulses which reach it.

DEMONSTRATIONS.

Comparison of the reflex actions obtained by stimulating the skin and a nerve trunk of a beheaded frog.

The purposeful character of reflex actions.

The summation of stimuli in the spinal cord.

The inhibition of reflex action in a frog, (*a*) through the strong stimulation of an afferent nerve; (*b*) through stimulation of the optic lobes.

XVIII. THE BRAIN.

THE MEDULLA OBLONGATA.

The medulla, besides being the pathway of nerve fibres connecting the brain and spinal cord, contains a number of automatic and reflex nerve centres which especially preside over the "organic" functions of the body. Among the nerve centres are included,—a respiratory centre; a cardio-inhibitory centre; a diabetic centre; a vaso-motor centre; centre for deglutition; centre for reflex secretion of saliva; a vomiting centre; centre for movements of œsophagus and stomach; and probably centres for the coördination of movements of the body.

The medullary centres, though capable of independent action, are no doubt normally under the influence of other similar centres in higher parts of the brain.

THE CHANGES PRODUCED IN AN ANIMAL BY THE REMOVAL OF ITS CEREBRUM.

A frog or a pigeon bears well the extirpation of the cerebrum, but a mammal sooner or later succumbs to such an operation.

The loss of the cerebrum involves the loss of spontaneous movement; an animal without that organ stirs only in answer to a stimulus.

With the loss of its cerebrum an animal appears to lose its faculty of *perception* and its power of forming *judgments*. The deterioration of the animal is in its psychical powers.

The aspects of a frog and of a pigeon after removal of the cerebral lobes are nearly normal. Food is not voluntarily taken, though it is swallowed when placed in the mouth. No sign of fear can be aroused.

The most complex coördinated movements may still be carried out. The balancing and swimming of a frog, and the flight of a pigeon whose cerebral hemispheres have been removed. Such an animal appears to retain its normal sensations. A frog deprived of its cerebrum avoids obstacles in leaping.

The same general results follow the destruction of the cerebrum in a mammal. A rabbit or a rat so treated ceases to notice food. Its gaze is attracted by a moving light, and it may utter plaintive cries and leap on being stimulated. Its *sensations* are preserved but its *perceptions* are lost.

THE LOCALIZATION OF FUNCTION IN THE CEREBRUM.

THE STRUCTURE OF THE CEREBRUM.

The interior of the cerebral hemispheres is chiefly composed of masses of nerve fibres which terminate in the cortex. The nerve cells of the cerebrum are contained in the cortical substance, a thin sheet of gray matter which overlies the convoluted surface of the hemispheres.

In general, the cerebrum may be considered to be the seat of thought, of consciousness, and of will power.

It is not certain whether the manifold functions of the cerebral cortex are separately localized in the various convolutions, or whether the whole brain is to be regarded as a complicated machine in which the activity of one part involves that of all the rest.

The effect of gradual removal of a pigeon's brain is a gradual loss of psychical power in the animal.

In certain pathological conditions, as in the disease *aphasia*, there is strong suggestion of a localization of function in the cortex.

There may be produced in an animal definite movements or signs of sensation, as a result of the electrical stimulation of well defined areas of the cerebral convolutions. Mechanical or chemical stimulation of the cortex is not followed by positive results.

Removal of a "motor" area of the cortex is said by some to be followed by a loss of voluntary control over the muscles formerly excited by the stimulation of that area. Removal of a "sensory" area is said in like manner to involve a loss of the appropriate sensations.

The results supporting the theory of localization, as obtained in the experiments of Fritsch and Hitzig, of Ferrier and of Munk.

The nature of the phenomena brought out by artificial stimulation of the cortex, and of those which follow the extirpation of various areas.

There is a gradual recovery from the motor paralysis or loss of sensation which follows removal of a limited area of the cortex.

In this recovery the function of the lost part has not been assumed by any definite homologous area in another part of the brain.

According to the experiments of Goltz, there is no distinct localization of function in the cerebral cortex; but a gradual loss of psychical power, of sensation and of definite voluntary motion follows extirpation of any part of the cerebral convolutions in the dog, and these disturbances are more extensive and less readily recovered from, the more widespread the lesion.

After suffering such an operation an animal responds in a reflex manner to stimuli much more readily than usual.

Parts of the brain below the cerebrum are no doubt capable of carrying out independently complicated activities in which simple sensations are involved.

The difference between *psychoses* and *neuroses*.

Cerebral "reaction time."

THE CORPORA STRIATA AND THE OPTIC THALAMI.

The so-called "basal ganglia" are masses of gray tissue containing many nerve cells. Most of the fibres of the crura cerebri pass into the basal ganglia before proceeding to the cortex of the brain. The anterior fibres of the peduncles enter the corpora striata and the posterior fibres join the optic thalami, before continuing into the cerebral substance. The nerve fibres which enter the basal ganglia are no doubt largely connected with nerve cells found there.

When a lesion involves both the corpus striatum and optic thalamus of one side, there is loss of voluntary motion and of sensation on the opposite side of the body, without necessary impairment of intellectual faculties.

It probable that the basal ganglia act as sets of relay stations which mediate between the cerebral cortex and nervous centres in lower parts of the brain and spinal cord.

There is some reason to believe that the corpora striata are chiefly concerned in the modification of volitional impulses passing to it from the cerebral convolutions; and that the optic thalami receive the sensory impulses before they proceed to the surface of the brain.

Injury to the optic thalami is followed by blindness or imperfection of vision.

THE CORPORA QUADRIGEMINA.

These bodies correspond to the corpora bigemina, or optic lobes, of the frog and pigeon.

The nervous centres for the coördination of the movement of the eyeballs with the contraction of the pupils lie in or below the anterior half of the corpora quadrigemina.

The manner in which the actions of these centres are asso-

ciated; when the visual axes are converged the pupils contract, when the axes becomes parallel the pupils dilate.

Movements of the opposite eye are brought about by the stimulation of the corpora quadrigemina on one side.

Extirpation of the corpora quadrigemina, or of the optic lobes, on one side produces blindness in the opposite eye.

The seat of visual *sensations* appears to be in the corpora quadrigemina, but visual *perceptions* are lost when the cerebral cortex is destroyed.

Other physiological functions, as that of respiration, probably are regulated by special centres situated in the corpora quadrigemina.

THE CEREBELLUM.

The structure of the cerebellum and the manner of its association with the rest of the brain.

The chief function of the cerebellum is to serve as a collection of nerve centres whose action maintains the equilibrium of the body and coördinates its movements.

Lesions of the cerebellum artificially produced are followed by unsteadiness of gait, and when a large amount of nervous substance is lost complete failure of coördination is the result.

Lateral lesions produce more effect than those established in the median line.

Extensive asymmetrical injury of the cerebellum, as of section of the middle peduncle on one side, produces remarkable *forced movements* of the animal, together with a peculiar rolling back and forth of the eyes.

Section of one of the crura cerebri is also followed by forced movements, as also are injuries of the corpora striata and optic thalami, or even of the cerebral cortex alone.

The passage of a galvanic current through the back part of the head produces a sensation of giddiness and a rolling motion of the eyes.

There is no reason to believe that the cerebellum is connected with the sexual functions. The special sexual centres appear to be situated in the lumbar region of the spinal cord.

THE SEMICIRCULAR CANALS AND THEIR RELATION TO THE MAINTENANCE OF THE EQUILIBRIUM OF THE BODY.

THE STRUCTURE OF THE SEMICIRCULAR CANALS.

The planes of the three membranous canals lie approximately in the three dimensions of space.

The ampullar enlargement of each canal and the modified termination of the filaments of the auditory nerve within it.

The cavity of each canal communicates with that of the utricle.

The whole membranous labyrinth is filled with *endolymph.*

THE EFFECT OF CUTTING THE SEMICIRCULAR CANALS IN A PIGEON.

When one of the semicircular canals of a pigeon is divided, remarkable disturbances of equilibrium immediately follow. When one of the horizontal canals is cut the head moves from side to side; when one of the vertical canals is operated on the movement is up and down. These disturbances of equilibrium become more marked when a number of canals is divided, and the animal places its head in unusual positions with respect to to the body. Gradual recovery takes place if but one or two canals be injured.

Injury of the semicircular canals of the mammal is followed by the same general results as in the case of the pigeon.

These results are not due to partial muscular paralysis, nor probably to unusual auditory sensations.

THE SENSE OF EQUILIBRIUM.

The maintenance of the equilibrium of the body requires the coördinated activity of complicated nerve-muscular mechanisms. The afferent impulses which determine the action of this motor apparatus, may arrive from different sources.

The body must know its position in reference to surrounding objects in order to maintain its equilibrium. Such a knowledge of the body's position may be attained through *visual* sensations, *tactile* sensations and *muscular* sensations.

But it has been shown that a person may be conscious of a change of position without the excitement of any of the foregoing sensations. The impulses which bring this information are supposed by some to arise in the semicircular canals. It is possible that movements of the body may cause a change of pressure of the endolymph within the semicircular canals upon the nervous mechanisms there, the intensity of excitement in each ampulla depending upon the direction of the movement. The truth of this hypothesis is not established.

The various means by which vertigo may be produced.

THE CRURA CEREBRI AND PONS VAROLII.

These bodies contained considerable gray matter, but the chief functions we can ascribe to them are those in which they serve as connecting links between different parts of the central nervous system. Marked disturbance of equilibrium follows injury of either the crura cerebri or the pons varolii.

THE BLOOD SUPPLY OF THE BRAIN.

The amount of blood supplied to the brain is, in proportion to the size of the organ, probably small.

When the brain is exposed it is found to undergo rhythmic alterations of volume occasioned by the heart beats and respiratory movements.

During its periods of activity the brain appears to receive more blood than when at rest.

Owing to the rigid cranial envelope sudden variations of the amount of blood in the brain subject its substance to such changes of pressure as may affect the consciousness.

The blood supply of the brain is no doubt under elaborate vaso-motor regulation.

DEMONSTRATIONS.

The phenomena exhibited by a pigeon and by a frog after removal of the cerebral hemispheres.

The phenomena of "forced movements."

The effects following section of the semicircular canals in the pigeon and the frog.

XIX. THE EYE AND SIGHT.

The anatomical mechanism whose excitement gives rise to a simple sensation consists of (1) a peripheral "sense organ," (2) an afferent nerve, (3) a central nerve-cell organ.

It is only the activity of the central organ which directly affects consciousness. It is often difficult to determine in which part of the sense apparatus the disturbance which gives rise to a sensation originates.

Specific nerve energy.

The difference between simple *sensations* and *judgments*.

THE STRUCTURE OF THE EYE AND PARTS NEAR IT.

The small third eyelid which represents the nictitating membrane of some animals.

The perforated lachrymal papillæ. The lachrymal gland. The Meibomian glands.

The six muscles for the movement of the eyeball.

The eyeball. The oblique entrance of the optic nerve. The *sclerotic* coat and *cornea* continuous with it. The radius of curvature of the cornea is smaller than that of the remaining surface of the eyeball. The *choroid* coat; its blood-vessels, pigment-cells and ciliary processes. The *iris*; its inner circular and outer radial plain muscle fibres; its vessels, nerves and pigment. The *ciliary* muscles. The *crystalline lens;* its *suspensory ligament.* The *vitreous humour* and *hyaloid membrane.* The *aqueous humour.* The *anterior* and *posterior* chambers of the eye. The *canal of Schlemm.* The *retina;* the *ora serrata;* the *macula lutea* and *fovea centralis;* the blood-vessels of the optic nerve and their distribution in the retina.

Commencing at its anterior surface there may be recognized in the human retina ten distinct layers; (1) Membrana limitans interna; (2) layer of nerve fibres; (3) layer of nerve cells;

(4) inner molecular layer; (5) inner nuclear layer; (6) outer molecular layer; (7) outer nuclear layer; (8) membrana limitans externa; (9) layer of rods and cones; (10) layer of tesselated, pigment-holding cells.

The *macula lutea* or yellow spot is free from blood-vessels except at its margin. The blood-vessels of the retina ramify in the nerve fibre layer and their capilarlies do not extend outward beyond the inner nuclear layer.

The *fovea centralis* contains only the retinal cones, the rods being there absent.

The pigment-free part of the choroid which forms the *tapetum* in some animals.

THE EYE AS AN OPTICAL INSTRUMENT.

When a ray of light falls on the retina we become conscious of a sensation of light.

In order that we may become aware of the form of a distant object an image of it must be thrown upon the retina.

The eye is a camera made up of a dark chamber to which the light is admitted through a diaphragm, the iris; two refracting media, the cornea and crystalline lens, intercept the light before its entrance into the retinal chamber.

The refracting power of a lens depends (*a*) upon the curvature of its surface, (*b*) upon the refracting power of its substance.

The foci of all the refracting media of the eye fall upon an *optic axis* which meets the retina a little above and inside of the fovea centralis.

We may calculate the path of all oblique rays entering the eye by assuming that they meet the optical axis at a "nodal" point and leave the axis in a direction parallel to the first from a second nodal point. The nodal points are near together on the optical axis within the lens.

The refraction of a ray of light entering the eye occurs chiefly at the anterior surface of the cornea and at the anterior and posterior surfaces of the lens.

When the head is plunged under water the refraction by

the cornea is nearly done away with; hence the marked compensatory curvature of the fish's lens.

The anterior and posterior surfaces of the cornea being nearly parallel, they may be regarded as one.

The refractive powers of the aqueous and vitreous humours being nearly the same as that of the cornea, we may regard the refracting surfaces of the lens as three, the anterior surface of the cornea, the anterior aud posterior surfaces of the lens.

It is calculated that the focus of the refracting media of the eye lies, for parallel rays, 14.647 mm. behind the posterior surface of the lens and 22.647 mm. behind the anterior surface of the cornea.

ACCOMMODATION.

The focal distance at which a distinct image of an object may be formed by light passing through a refracting surface, the refractive index remaining the same, depends, (*a*) upon the curvature of the surface, (*b*) on the angle which the entering rays form with it. In order that an image which is thrown upon a certain fixed plane may remain distinct when one of those factors is changed, the other factor must undergo a compensatory change.

If this *accommodation* is not brought about, the image is replaced by a series of blurred "diffusion circles."

Accommodation in the human eye as illustrated by "Scheiner's experiment." The near limit of distinct vision.

In the normal or *emmetropic* eye, the near limit is at a distance of ten to twelve centimetres; the far limit may be regarded as at an infinite distance. In the short sighted or *myopic* eye the near limit is brought within five to six centimetres distance of the cornea and the far limit at a variable but not considerable distance. In the far-sighted or *hypermetropic* eye, the near limit of distinct vision is some distance away, and a far limit does not exist. In the three cases, an image formed by rays parallel to the optical axis falls respectively *on* the retina, *before* it and *behind* it.

THE APPARATUS OF ACCOMMODATION.

While at rest, the eye is accommodated for objects at an extreme distance.

In accommodating for near objects two movements may be observed in the eye, (1) a narrowing of the pupil, (2) a change in the curvature of the anterior surface of the lens by which it become more convex.

In its normal condition the lens is an elastic body whose curved surfaces are somewhat flattened by the pressure of the inclosing suspensory ligament which is kept stretched by its attachment to the choroid. When the ciliary muscles contract, the choroid is pulled forward and the suspensory ligament is slackened, thus allowing the anterior surface of the lens to bulge outward.

THE MOVEMENTS OF THE PUPIL.

The pupil is contracted when light falls upon the retina, but is dilated in the dark. It is contracted when we accomodate for near objects, but it is dilated when we accommodate for distant ones. It is contracted when the optical axes converge and dilated when they become parallel.

The contraction and dilation of the pupil are active movements brought about respectively by the circular and the radial muscular fibres of the iris.

These movement of the pupil are the result of reflex and associated actions. When the movement is brought about by light falling upon the retina, the optic nerve is the afferent nerve of the reflex apparatus; the third or oculo-motor nerve is the efferent nerve whose excitement causes contraction, and the sympathetic is the efferent dilator nerve.

There is union between the reflex centres for movement of the pupils; for subjecting one eye to changes of illumination produces movement of the opposite pupil.

The action of drugs upon the pupil, as of atropin or physostigmin, is probably wholly local.

DEFECTS OF THE EYE AS AN OPTICAL APPARATUS.

The special defects of the myopic, hypermetropic and presbyopic eye.

The *spherical aberration* due to the form of the lens is probably insignificant in comparison with other optical defects of the eye. The refractive power of the lens varies in different parts of it. The most obvious use of the iris is to diminish spherical aberration by cutting off circumferential rays.

When light passes though a spherical lens it can throw a well defined image of larger dimensions upon a curved surface, like that of the retina, than upon a plane surface.

The refracting surfaces of the eye are not perfect sections of a sphere, but are often more convex along one meridian than another. Hence, lines having different directions cannot all be brought simultaneously to a focus on the retina. This leads to the defect known as *astigmation.*

Methods of determinating the *chromatic aberration* of the eye.

Entoptic phenomena.—Floating particles in the vitreous humour, the *muscæ volitantes.* Imperfections in the lens. Tears on the cornea. The observation of the margin of the pupil. The luminosity and the floating coloured clouds of the retina.

The refracting surfaces of the eye are not centred on the optic axis.

SENSATIONS OF VISION.

The part of the retina which is directly excited by light is the posterior layer of rods and cones.

The optic nerve itself is unirritable towards light. The *blind spot.* The shadows of the retinal blood-vessels seen as *Purkinje's figures.*

The amount of energy contained in a luminous wave may be exceedingly small.

The movement of pigment in the retinal epithelium under the influence of light.

The retinal pigments which are altered by light.

Both rods and cones are probably directly irritated by light; in certain animals the first and in others the second of these

elements seems to be absent. It has been conjectured that rods serve chiefly to give mere sensation of light, while the cones are adapted to permit of distinctness of vision.

The alternate spontaneous blindness of the two eyes.

Temporary blindness produced by pressure on the bulb.

THE RELATION OF THE DURATION AND STRENGTH OF THE STIMULUS TO THE SENSATION.

The sensation produced by a momentary flash of light has a much longer duration than the stimulus itself, when single flashes follow each other sufficiently rapidly the separate sensations are fused. The intervals between the flashes must be smaller the stronger the light in order that the separate sensations may be completely fused. The duration of the "after-image" is longer the stronger the light which caused the sensation.

The intensity of sensation varies with the intensity of illumination; but the relation of the variation of the intensities is not a sinple one.

Weber's law.—The increase of stimulus which is necessary to produce the smallest increase of sensation bears always the same proportion to the whole intensity of the stimulus which has already been applied.

THE DISTINCTION AND FUSION OF SIMULTANEOUS SENSATIONS.

Two objects appear as one if brought near enough together. In order to appear as two objects, the distance between their images on the retina must not be less than the diameter of a single retinal cone. In the human eye objects thrown thus near together in the fovea of the retina may still be distinguished apart. Toward the periphery of the retina the distinction is not nearly as fine.

Cause of the broken outline of fine lines which are drawn close together.

The distinction between cerebral and retinal visual areas.

The number of cones in the retina is much greater than that of the fibres in the optic nerve.

COLOUR SENSATIONS.

Besides the sensations of white and black, we may attain certain sensations of colour, the quality of each of which is determined by the wave length of the incident light. The spectral colours are *red*, *orange*, *yellow*, *green*, *blue*, *violet*. The fusion of blue and red produces another simple color, *purple*, not found in the spectrum.

All the hues of nature may be imitated by the proper fusion of the primary color sensations with each other or with white or black.

The origin of browns, and olive greens. Various methods and the results of mixing simple colour sensations.

The cause of the difference between the sensation obtained by the mixture of two colours on the retina and that derived from the mixture of the pigments themselves.

A colour is said to be more or less *saturated* according as it contains less or more of white light. No colour is absolutely saturated.

Every colour which is sufficiently illuminated appears white.

Colour sensation produced by electric stimulation of the eye.

Gray is a mixture of white and black.

Complementary colours are those which, when mixed on the retina, produce the sensation of white light.

The following are complemetary colours;—Red and green-blue; orange and cyan-blue; yellow and ultramarine-blue; greenish-yellow and violet; green and purple.

Any three colours, situated in the spectrum as far apart as possible, may, in proper porportions, together produced white; by varying the proportions, all of the other spectral colours may be derived from the three primary colours.

The *Hering* theory of colour sensation.

The *Young-Helmholtz* theory of colour sensation.

AFTER IMAGES.

The sensation of light lasting longer than the stimulus, an object may still be seen for a time after its removal from the field of vision; such sensations are known as *after images*. The after image is at first *positive*, or of the same brightness and colour as the stimulus; soon it becomes *negative*, or of brightness and colour complementary to the original stimulus.

Explanation of changes in after images as a result of retinal fatigue.

The successive fading of the colours of an after image.

The intrinsic light of the retina.

COLOUR BLINDNESS.

Some persons are incapable of acquiring certain colour sensations. The most common form of the defect is that of "red-blindness." To persons suffering from it, the colours rose-red and bluish-green are identical. They distinguish in the spectrum but two colors, calling them yellow and blue; under the yellow they include the red, orange, yellow and green, and blue and violet are called blue.

About 5 p. c., of the population are affected to some degree with red-blindness.

Temporary colour blindness induced by wearing coloured glasses, and by the ingestion of santonin.

A rarer form of colour-blindness is said to occur in which the sensation of red is preserved, but that of green is lost.

The demonstration of the yellow pigment of the macula lutea.

The perception of the mosaic of rods and cones of one's own retina.

In the waning twilight the red disappears first and the blue last; hence, red objects first become dark.

The psychical effects produced by viewing a landscape through differently coloured glasses.

VISUAL PERCEPTIONS.

The mind derives ideas from simple visual sensations; *sensations* give rise to visual *perceptions*.

The perception of the positions of objects. The localization of objects by vision is a subjective process. The images of objects are inverted on the retina.

Distinctness of vision diminishes from the centre to the periphery of the retina, as does also the appreciation of colour differences.

MODIFIED PERCEPTIONS.

Irradiation: bright objects appear larger than dark ones of the same size.

Simultaneous contrast: light and dark surfaces appear respectively brighter and darker when viewed together. The phenomena of coloured shadows. When a piece of gray paper is laid on a coloured surface and covered with tissue paper, the gray slip appears to have a colour complementary to that of the surface.

The blind spot is not perceived chiefly because no sensation is aroused by it.

The retina itself gives rise in the dark to luminous sensations.

Instrinsic coloured images of the retina. Lights produced by pressure on the eyeball. Effect of stimulating the eye or optic nerve.

Visual judgments of size. The only method of determining the relative size of objects is the comparison of the magnitude of their images thrown upon the retina; our estimation of their real size depends upon the distance from the eye at which they are believed to be situated. This distance seems greater when sub-divided by intervening objects; the apparent size of the moon in mid-sky and on the horizon; comparison of the lengths of two equal lines, one of which is sub-divided and the other not; the greater apparent size of objects in a fog. The appreciation of difference of size by contrast.

Judgments of the magnitude of angles.

VISION WITH TWO EYES.

In general, the reason why an object viewed with two eyes appears single is that the image of each point on it falls upon

"corresponding" or "identical" areas of the two retinas. Points on the inner side of one retina have their corresponding points on homologous parts of the outer side of the other.

MOVEMENTS OF THE EYEBALL.

The orbit and the eyeball form a ball and socket joint, the centre of rotation being 1.8 mm. behind the centre of the eye.

The reflex fixation of external objects which keeps the eyeballs at rest when the head is moved.

The "primary" and "secondary" positions of the eye. The position of the resting eye.

The rotation of the eye around its visual axis when the latter is changed from a primary to an oblique position.

The muscles of the eyeball and the movements brought about by their action.

The coördination of the movements of the eyeball. The double images that result when the coördination centre fails to act.

Apparent rotation of toothed wheels brought about by the rinsing motion.

False judgments of motion.

THE HOROPTER.

Distinct vision of objects can be had only when the images of their parts fall upon corresponding points of the two retinas. In any given position of the visual axes such corresponding points are projected outward upon some definite line or surface and this line or area of distinct vision is known as the *horopter*. The horopter changes its form or position with changes of direction of the visual axes. When standing erect and looking toward the horizon the horopter is upon the ground before the eyes. The precautions necessary in walking upon a hillside, or upon a level while looking through a prism.

THE JUDGMENTS THAT ARISE FROM BINOCULAR VISION.

By means of the movements of the two eye-balls and the images falling upon corresponding point of the two retinas, we

are enabled to form certain judgments concerning the form size and distance of objects.

Illustrations of the judgments concerning size and distance as depending upon the "muscular sense" of innervation of the eye-muscles.

When a solid object is viewed the images falling upon the two retinas cannot be identical; they, however, do not give rise to double vision, but are fused in the cerebrum so as to give the perception of single *solid* objects. The shading of an object largely assists in the formation of a judgment of its solidity.

Applications of the stereoscope.

When two different colours or white and black are viewed at the same time each by one eye, there is not a fusion of colour in the sensation but an alternate mastery one and the other.

The action of the accessory glandular and muscular mechanisms of the eye.

The reflex secretion from the lachrymal glands and the aid rendered by winking movements to the emptying of the lachrymal canals.

DEMONSTRATIONS.

Scheiner's experiment. Observation of the movements of the pupil. Astigmatism. The blind spot. Purkinje's figures. The mixture of colours upon a rotating disc. Complementary colours. After images. Tests for colour-blindness. The yellow spot. Irradiation. Simultaneous contrast. Judgments of distance. Judgments of motion. The stereoscope.

XX. THE EAR AND HEARING.

THE STRUCTURE OF THE EAR.

The organ of hearing may be considered to be made up of three parts;—an *external ear*, composed of the pinna and auditory meatus, the latter being separated by the tympanic membrane from the *middle ear* or tympanum. The tympanum contains the auditory ossicles, malleus, incus and stapes, and

its cavity opens upon the upper wall of the pharynx by means of the Eustachian tube; an *internal ear*, consisting of a membranous labyrinth, to which the auditory nerve is distributed, which is contained within a bony labyrinth; the two labyrinths are filled with fluid known respectively as the endolymph and the perilymph. The division of the bony labyrinth into vestibule, semicircular canals and cochlea. The fenestra rotunda and fenestra ovale are placed in the bony wall separating the tympanum respectively from the scala tympani of the cochlea, and from the vestibule. The membranous vestibule is composed of two sacs, the saccule and utricle, whose cavities are indirectly united. The membranous semicircular canals spring from the utricle, and the cavity of the saccule is continuous with that of the membranous canal of the cochlea. The auditory hair-cells upon the maculæ of the vestibular sacs and on the cristæ of the ampullæ of the semicircular canals. The otoliths within the sacs and canals.

The microscopic structure of the membranous cochlea and of the organ of Corti contained in it.

THE SPECIAL FUNCTIONS OF THE PARTS OF THE ACOUSTIC APPARATUS.

THE PINNA OR EXTERNAL EAR.

The modification of the concha in different animals. Its purpose is to collect the waves of sound from the external air.

THE MEMBRANA TYMPANI.

The curved surface and funnel-shape of the tympanic membrane. This membrane is easily set vibrating by air waves, and has no fundamental note of its own. Its peculiar shape adapts it for transmitting motions of great amplitude and small energy as motions of small amplitude and great energy.

The movements of the auditory ossicles. The ossicles form a sort of compound lever by which the oscillations of the tympanic membrane are exactly transferred to the membrane of the

fenestra ovale, but with diminished amplitude and correspondingly increased force.

The *tensor tympani* muscle serves by its contraction to prevent the tympanic membrane being pushed out too far.

The *laxator tympani* muscle probably by its contraction causes the ear-drum to move outward.

The *stapedius muscle* probably acts to prevent the stapes being driven too far into the fenestra ovale.

THE EUSTACHIAN TUBE.

This channel connecting the middle ear and the pharynx serves to keep the pressure within the tympanic cavity equal to that of the atmosphere. The tube is probably only opened during the act of swallowing.

THE GENERATION OF AUDITORY SENSATIONS.

THE MEMBRANOUS LABYRINTH.

The filaments of the auditory nerve end in the maculæ and cristæ of the internal ear and in the basilar membrane of the cochlea. It is supposed that vibrations of the endolymph set these end-organs in corresponding motion, thus mechanically stimulating the auditory nerve.

The transmission of sound through the bones of the skull; hearing without a tympanic membrane.

Sounds may be divided into *musical tones* which are caused by rhythmic or periodic vibrations of the air, and *noises* which are due to non-periodic vibrations.

Sounds are distinguished by the three characters of *loudness*, *pitch* and *quality*. The physical peculiarities implied in these terms.

The physical range of audible tones.

Each musical tone is made up of a *fundamental* note, which determines the pitch, with which a greater or less number of *overtones* are combined, the latter determining the *quality* of the tone.

Nearly every body capable of periodic vibration has a fundamental note of its own.

Sympathetic vibrations. The analysis and synthesis of musical tones.

There is reason to think that the organ of Corti may be regarded as a musical instrument capable of responding by sympathetic vibration to all audible tones.

It has been supposed that the auditory hairs upon and the otoliths near the maculæ and cristæ of the labyrinth are concerned in the reproduction of irregular vibrations known as noises.

The simplest aural apparatus known is a mere sac whose walls are set with hair-cells, and whose cavity is filled with fluid containing otoliths.

When single sounds are repeatsd with sufficient rapidity they fuse into a continuous tone whose pitch is determined by the rate at which the single sounds succeed each other.

Tones produced by vibrations recurring less than 30 times a second are not heard. The upper limit of auditory sensation is reached when vibrations recur 38,000 times per second.

The power of distinguishing pitch differs much in different parts of the scale.

The subjective nature of sound. Individual differences in the appreciation of tones.

AUDITORY JUDGMENTS.

Any stimulation of the auditory nervous apparatus is interpreted as due to sound waves.

From the loudness, quality and pitch of sounds, we form judgments as to their direction or distance. The nature of ventriloquism.

XXI. THE ORGAN AND SENSE OF SMELL.

The cavity of the nose on each side of the nasal septum is divided functionally into a lower respiratory and upper olfactory chamber. The olfactory mucous membrane, to which the

olfactory nerve is distributed, lines the upper and middle turbinated parts of the fossæ and the upper part of the septum. The ciliated epithelium and mucous glands of the respiratory chambers of the nose.

The termination of the nerve fibres in the olfactory cells of the upper chamber.

THE ORIGIN OF SENSATIONS OF SMELL.

Odorous particles are carried by diffusion into the olfactory chamber of the nose, or drawn into it by active inhalation.

Odorous bodies must come into contact with the olfactory mucous membrane in order to produce a sensation, and the particles must not be in liquid form. Filling the nose with an odorous liquid causes no sensation of smell. When several odours are simultaneously inhaled, the peculiarity of each may be distinguished.

Localization of an odour by the sense of smell is very imperfect.

The sensation requires some time to develop itself after application of the stimulus and may last for a considerable time.

Certain pungent substances, as ammonia, give rise to sensations through the nose which are not those of smell proper, but are probably due to stimulation of the fifth nerve. There may be sensations of smell of purely subjective origin.

XXII. THE ORGAN AND SENSE OF TASTE.

The glossopharyngeal and the lingual nerves are the special nerves of taste.

The modified termination of the gustatory nerves in the mucous membrane of the tongue and palate.

Many sensations which we are accustomed to distinguish as those of taste are really sensations of smell.

Sapid substances may be classified as sweet, sour, saline and bitter. They act in solution as chemical stimuli.

Sensations of taste may arise from mechanical or electrical stimulation of the gustatory apparatus.

XXIII. GENERAL SENSIBILITY AND SENSATIONS OF TOUCH.

The distribution and modified terminations of sensory nerves.

We possess a certain faculty of *general sensibility* which gives rise to a consciousness of irritation in the body without enabling us to localize the stimulus or distinguish its nature. Such are the sensations due to irritation of a nerve trunk or of the viscera. Such sensations readily merge into those of pain.

The more special sensations of feeling are those derived from *touch*, *temperature* and *muscular activity*.

TACTILE SENSATIONS.

SENSATIONS OF PRESSURE.

The smallest difference which can be distinguished between two unequal weights laid upon the skin is proportional to the magnitude of the weights.

When separate sensations of contact succeed each other with sufficient rapidity they become fused.

Not all parts of the skin are equally sensible to variations of pressure.

Sensations of contact are present when the intensity of the pressure is varied, and fade away when it becomes constant.

A cold body is judged to be heavier than a warm one of equal weight.

There is reason to believe that there exist tactual nerves distinct from those of general sensibility.

TACTILE PERCEPTIONS AND JUDGMENTS.

Sensations of contact are referred generally to definite localities on the skin. The erroneous judgments that arise from the irritation of the nerves of an amputated limb. Mistaken judgments arising when a marble is rolled between the tips of two crossed fingers.

The power localizing contact upon the skin is not the same in all parts. The division of the skin into tactual areas.

The power of localization is most marked upon the tip of the tongue and the palmar surface of the finger, and least marked upon the forearm, sternum and back.

The fineness of tactile perception is greatly increased by exercise.

THE TEMPERATURE SENSE.

Bodies warmer or colder than the skin when in contact with it give rise to sensations of heat or cold. The erroneous judgments that may arise from artificially rendering the two hands of different temperatures.

The range of finest distinction of temperature is included between limits which lie near the body temperature.

Not all parts are equally sensitive to variations of temperature.

There are probably special afferent temperature nerves which are irritated by variations of temperature.

THE MUSCULAR SENSE.

We commonly estimate the weight of bodies by observing the intensity of muscular exertion necessary to lift them.

Muscular sensations are probably peripheral in origin.

The effects following diminution of tactile and muscular sensibility in *locomotor ataxy.*

Judgments which arise from the muscular sense.

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